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GJ-HAN-92
Tank C-110

Hanford Tank Farms Vadose Zone

Tank Summary Data Report for Tank C-110

November 1997

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U.S. Department of Energy

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CONTRACT NO.: DE–AC13–96GJ87335
TASK ORDER NO.: MAC-98-09
CONTROL NO.: 3100-T98-0287

November 21, 1997

Project Manager
Department of Energy S7-54
Richland Operations Office
825 Jadwin Ave.
Richland, WA 99352
ATTN: David Shafer

Subject: Contract No. DE–AC13–96GJ87335—Submittal of Tank Summary Data Report for Tank C-110 (GJ-HAN-92)

Dear Mr. Shafer:

Enclosed is one (1) copy of the subject Tank Summary Data Report (TSDR). This report is being submitted for your information/records and should be considered final. By cover of this letter a copy is being provided to DOE-GJO for their records.

Should technical questions or comments arise, please do not hesitate to contact John Brodeur or myself at (509) 946-3635.

Sincerely,

James F. Bertsch
Project Manager

JFB/jmm
Enclosure
cc/enc: V. A. Cromwell, DOE-GJO

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GJ–HAN–92
Tank C-110

Vadose Zone Characterization Project at the Hanford Tank Farms

Tank Summary Data Report for Tank C-110

November 1997

Prepared for
U.S. Department of Energy
Albuquerque Operations Office
Grand Junction Office
Grand Junction, Colorado

Prepared by
MACTEC-ERS
Grand Junction Office
Grand Junction, Colorado

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at the Hanford Tank Farms

Tank Summary Data Report for Tank C-110

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Executive Summary

The U.S. Department of Energy (DOE) Richland Operations Office tasked the DOE Grand Junction Office (GJO) with performing a baseline characterization of the gamma-ray-emitting radionuclides that are distributed in the vadose zone sediments surrounding the single-shell tanks (SSTs) at the Hanford Site. Information regarding vadose zone contamination was acquired by logging the monitoring boreholes positioned around the SSTs using a spectral gamma logging system (SGLS). This system employs a high-purity germanium detector and is designed to acquire laboratory-quality assays of the gamma-emitting radionuclides in the sediments. This report documents the spectral gamma-ray logging results obtained from the monitoring boreholes that surround tank C-110.

Tank C-110 is categorized as an assumed leaker with interim stabilization and intrusion prevention completed. The tank is currently listed as containing dilute-complexed waste that consists of 177,000 gallons (gal) of sludge (estimated to include 28,000 gal of interstitial liquid) and 1,000 gal of supernatant liquid (Hanlon 1997).

Cesium-137 (^{137}Cs) contamination and very limited cobalt-60 (^{60}Co) and europium-154 (^{154}Eu) contamination was detected in the vadose zone sediments surrounding this tank.

^{137}Cs contamination was detected in the upper portions of all the boreholes surrounding the tank. This near-surface contamination is probably the result of surface spills that migrated into the backfill material around the tank.

The ^{137}Cs contamination was also detected in two boreholes (30-10-02 and 30-07-11) at depths from about 44 to 74.5 ft. This contamination may be the result of a tank or pipeline leak that has migrated into the Hanford formation sediments beneath the tank. The contamination appears to be correlatable and continuous between the two boreholes. Shape factor analysis of the contamination detected in borehole 30-10-02 indicates that the contamination is in the formation around the borehole, rather than adjacent to the borehole casing. The ^{137}Cs concentrations measured in borehole 30-07-11 were too low to perform a shape factor analysis.

The ^{137}Cs, ^{60}Co, and ^{154}Eu contamination detected in borehole 30-07-11 from 1 to 4 ft is probably from material remaining within a nearby transfer line. An investigation conducted in 1992 indicated that the contamination detected in borehole 30-07-11 was actually contained in an improperly designed salt-well transfer line (Winkler 1992).

A review of historical gross gamma-ray logs for borehole 30-10-09 indicates that a leak may have occurred in tank C-110 before 1975. The anomalous gross gamma-ray activity from about 43 to 60 ft in borehole 30-10-09 appears to have decreased to background levels by 1980. On the basis of the apparent decay rate observed in the historical logs from January 1975 through January 1978, the contaminant responsible for this activity may have been ruthenium-106 (^{106}Ru), which has now decayed away.

1.0 Introduction

1.1 Background

The U.S. Department of Energy (DOE) Richland Operations Office tasked the DOE Grand Junction Office (GJO) with characterizing and establishing a baseline of man-made radionuclide concentrations in the vadose zone surrounding the single-shell tanks (SSTs) at the Hanford Site. These tasks are being accomplished using spectral gamma-ray borehole geophysical logging measurements made in the boreholes surrounding the tanks. The primary objective of this project is to provide data on the tanks for use by DOE organizations. These data may also be used to develop an SST Closure Plan in compliance with the Resource Conservation and Recovery Act and to prepare an Environmental Impact Statement for the Tank Waste Remediation Systems program.

1.2 Scope of Project

The scope of this project is to locate and identify the gamma-ray-emitting radionuclides and determine their concentrations in the vadose zone sediment by logging the monitoring boreholes around the SSTs with a Spectral Gamma Logging System (SGLS). Additional details regarding the scope and general approach to this characterization program are included in the project management plan (DOE 1997c) and baseline monitoring plan (DOE 1995b). This project may help to identify possible sources of any subsurface contamination encountered during the logging and to determine the implications of the contamination for Tank Farm operations. The acquired data will establish a contamination baseline that can be used for future data comparisons, for tank-leak verifications, and to help develop contaminant flow-and-transport models.

1.3 Purpose of Tank Summary Data Report

A Tank Summary Data Report (TSDR) will be prepared for each SST to document the results of the spectral gamma-ray logging in the boreholes around the tank. Each TSDR provides a brief review and a summary of existing information about a specific tank and an assessment of the implications of the spectral gamma-ray log information, including recommendations on future data needs or immediate corrective action, where appropriate. Appendix A of each TSDR presents logs of radionuclide concentrations versus depth for all boreholes around that specific tank. A comprehensive Tank Farm Report will be prepared for each tank farm after completion of characterization logging of all boreholes in the subject farm.

2.0 Spectral Gamma-Ray Log Measurements

2.1 Data Acquisition and Processing

The concentrations of individual gamma-ray-emitting radionuclides in the sediments surrounding a borehole can be calculated from the activities in the gamma-ray energy spectra measured in the borehole using calibrated instrumentation. Spectral gamma-ray logging is the process of collecting gamma-ray spectra at sequential depths in a borehole. Figure 1 shows a gamma-ray spectrum with peaks at energies, from 0 to 2,700 kilo-electron-volts (keV), that are characteristic of specific radionuclides. The spectrum includes peaks from naturally occurring radionuclides ^{40}K, ^{238}U, and ^{232}Th (KUT) and from man-made contaminants (e.g., ^{137}Cs and ^{60}Co). Gamma-ray source concentrations are cited in terms of picocuries per gram (pCi/g), even though this unit technically describes decay rate per unit mass of sample rather than concentration. The use of decay rate per unit mass is widespread in environmental work, where health and safety issues relate to the radioactivity, not the chemical concentration.

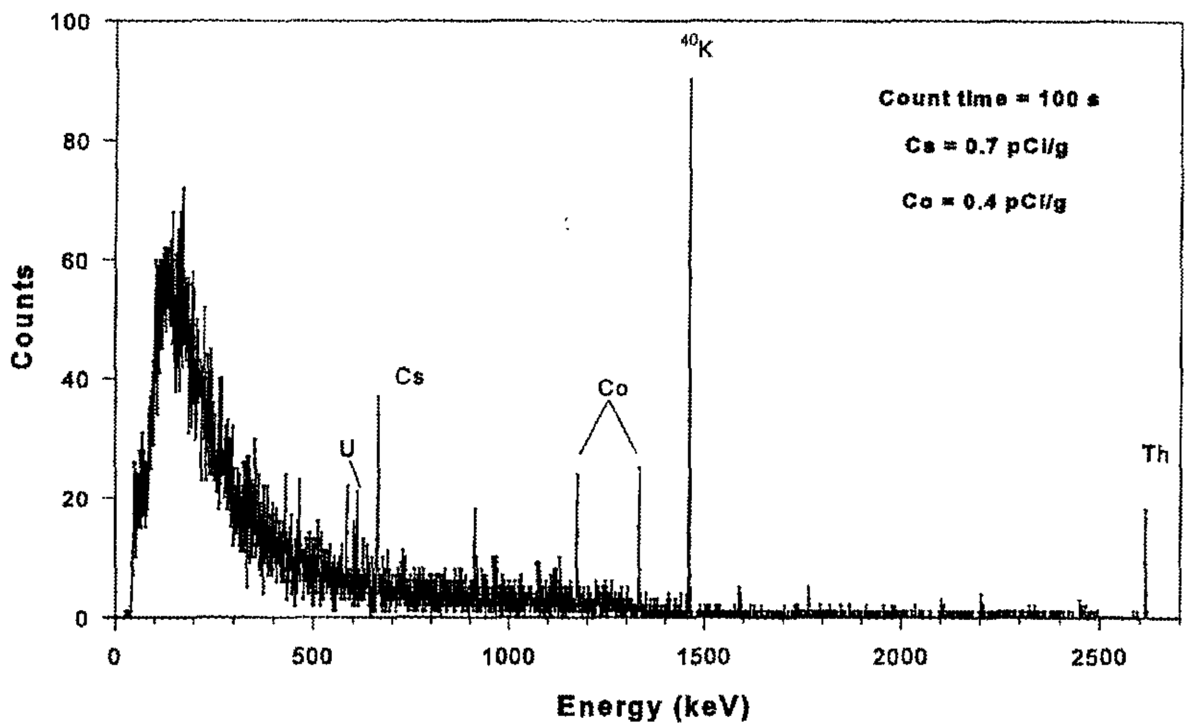

Figure 1. Gamma-Ray Spectrum

Data are acquired in boreholes near the tanks according to methods described in the logging procedures (DOE 1997b). Typical counting times at each measurement position are about 100 seconds (s), with a spectrum being collected every 0.5 foot (ft) along the length of the borehole.

Long data acquisition times can reduce the uncertainties in the calculated concentrations presented on the logs. However, economic and time constraints limit the amount of time available for data collection. The statistical uncertainty for gamma rays emitted from low-activity radionuclides such as ^{238}U and ^{232}Th can be high for this counting time, and the logs for these radionuclides will show high levels of statistical uncertainty, as evidenced on the logs by scatter in the plotted data and wide confidence intervals.

The minimum detection level (MDL) of a radionuclide represents the lowest concentration at which the positive identification of a gamma-ray peak for that radionuclide is statistically defensible. The spectrum analysis program calculates the MDL for a particular peak on the basis of a statistical analysis of the spectral background level in the vicinity of the peak. The same equations that translate peak intensities into decay rates per unit-sample mass also translate the MDLs from counts per second (cps) to picocuries per gram. A description of the MDL calculation is included in the data analysis manual (DOE 1997a).

The gamma-ray spectra measured in a borehole are processed using a variety of software programs to obtain the concentrations of individual gamma-ray-emitting radionuclides. All the algorithms used in the concentration calculations and their application is discussed in the data analysis manual (DOE 1997a). These calculated data, which are usually presented as vertical profiles, are used to make an interpretation of vadose zone contamination associated with each borehole. When data from all the boreholes associated with a specific tank have been processed and interpreted, a correlation interpretation is made of the vadose zone contamination surrounding each tank.

The initial SGLS calibration report (DOE 1995a) contains the results obtained from operating the logging tools in calibration models. The calibration report presents the mathematical functions used to convert the measured peak area count rates to radioelement concentration in picocuries per gram. The SGLS is routinely recalibrated (DOE 1996) to ensure the accuracy of the calculated radionuclide concentrations. The calculated radionuclide concentrations derived with these conversion factors may be as much as 14 percent higher than the actual in situ concentrations because the concentrations of the calibration models are expressed in terms of gamma-ray activity per unit-sample mass of *dry* bulk material. However, the measurements made in the calibration models were in a water-saturated environment. The conversion factors in the calibration report (DOE 1995a) are strictly applicable only when the logged formation has the same water content as the calibration-model test zones. The vadose zone contains pore-space water in various percentages of saturation from near 0 percent to near 100 percent, and the boreholes are logged dry. Corrections for pore-space water cannot presently be applied to the vadose zone measurements because the in situ water content is not being measured.

The calibration data from which conversion factors were derived were recorded with a logging tool in a borehole drilled through a uniform homogeneous isotropic gamma-ray-source material. If the gamma-ray sources in the borehole being logged are not uniformly distributed in the sediments, the conversion factor produces apparent concentrations. The concentrations calculated for the top and bottom of a borehole are also apparent concentrations, because the source-to-detector geometries at these locations differ from the source-to-detector geometries during calibration.

When gamma-ray spectra are measured in cased boreholes, a casing correction must be applied to the peak count rates to compensate for gamma-ray attenuation by the casing. This correction function is described in the calibration report (DOE 1995a), and the data analysis manual (DOE 1997a) describes the application of the correction function in the data processing.

2.2 Shape Factor Analysis

Insights into the distribution of the radionuclides identified by the SGLS can be provided by using an analytical method known as shape factor analysis (Wilson 1997). Shape factor analysis takes advantage of 1) the SGLSs ability to record the specific energies of detected gamma rays, and 2) the Compton downscattering caused by the interaction of gamma rays with matter between the gamma-ray source and the detector.

Compton scattering results in higher energy photons being converted to lower energy photons; hence, Compton scattering within and outside of the detector accounts for the low-energy continuum in a pulse height spectrum. Many factors exterior to the detector influence the low-energy portion of the spectrum of gamma rays incident on the detector and thereby affect the low-energy continuum in the pulse height spectrum. Wilson (1997) has shown that variations in gamma-ray source distribution relative to a borehole produce measurable changes in the shapes of the pulse height spectra recorded by logging the boreholes. The spectral shape changes are quantified by ratios of counts from various portions of the pulse height spectrum, and these ratios are used to assess the distribution of the source.

Shape factor analysis can also be used to identify the presence of brehmsstrahlung radiation from the beta-emitting radionuclide ^{90}Sr. Beta particles, emitted from the radioactive decay of ^{90}Sr, interact with the electromagnetic fields within the substances they traverse. The deflection and resulting deceleration of the beta particles produce x-rays, known as brehmsstrahlung radiation, which are detected in the lower energy portion of the gamma-ray spectrum. In instances of high total gamma-ray activity, a preponderance of lower energy gamma radiation may be due to the presence of beta emitters such as ^{90}Sr.

Additional information on shape factor analysis theory is provided in Wilson (1997).

2.2.1 Specific Shape Factors

As stated previously, the ratios of gamma-ray counts from various portions of a spectrum are indicators of gamma-ray source distribution. Three ratios are used in shape factor analysis. These ratios, known as shape factors, are designated CsSF1, CoSF1, and SF2.

- CsSF1 is the ratio of the total number of counts in the continuum window (60 to 650 keV) to the counts in the ^{137}Cs peak. This shape factor is useful for evaluating the distribution of the radionuclide ^{137}Cs.

- CoSF1 is the ratio of the total number of counts in the continuum window (60 to 650 keV) to the sum of the counts in the two ^{60}Co peaks (1173 and 1332 keV). This shape factor is useful for evaluating the distribution of the radionuclide ^{60}Co.

- SF2 is the ratio of the total number of counts in the lower energy portion of the continuum window (60 to 350 keV) to the counts in the higher energy portion of the continuum window (350 to 650 keV). This parameter is somewhat sensitive to the radionuclide distribution, but is most applicable to the identification of the beta emitter ^{90}Sr and in distinguishing remote ^{137}Cs or ^{60}Co from ^{90}Sr.

At low concentrations, high uncertainties in the ^{137}Cs and ^{60}Co peak count rates and in the net continuum count rates cause large errors in the calculated values of CsSF1 and CoSF1, respectively. A minimum count rate of 1 cps must be present for the calculated CsSF1 to be meaningful, and a minimum count rate of 2 cps must be present for CoSF1 (Wilson 1997).

The values of CsSF1, CoSF1, and SF2 also become less reliable as the radionuclide concentrations and count rates become very high and the dead time increases. Inaccuracies in the measurement of the spectral regions occur when system dead time increases to above about 20 percent. The effect on shape factors is relatively small for dead times up to 40 percent. For measurements made at dead times below 20 percent, distortion of the spectrum is negligible (Wilson 1997).

2.2.2 Interpretation of Shape Factors

Values of CsSF1, CoSF1, and SF2 that can be expected for radionuclides in various distributions were established from investigations by Wilson (1997). These distributions are: 1) contamination confined to the borehole region, such as when contaminants occur on the borehole casing, 2) contamination uniformly distributed throughout the formation around the borehole, and 3) contamination in the formation but at discrete locations remote from the detector. The expected CsSF1, CoSF1, and SF2 values for various distributions of ^{137}Cs are summarized below.

^{137}Cs or ^{60}Co Source Distribution	Spectral Shape Factor	
	CsSF1 or CoSF1	SF2
Inside of 6-inch (in.) casing	4.5 - 5.5	2.8
Outside of 6-in. casing	6.8 - 7.4	2.8
Uniformly distributed in formation	13 - 15	3.5
Discrete source 10 centimeter (cm) radial distance	~ 19	~ 3.8
Discrete source 30 cm radial distance	~ 37	~ 4.2
Discrete source more than 50 cm radially distant	80 - 100	4.4 - 5.0

When CsSF1, CoSF1, and SF2 values exceed those listed, the presence of ^{90}Sr is suggested. However, photons from intense gamma-ray sources remote from the borehole can also produce spectra with high CsSF1 and CoSF1 values, indicating that elevated values of these two shape factors alone are not sufficient for a ^{90}Sr identification. The presence of ^{90}Sr can usually be inferred with confidence when SF2 significantly exceeds the extreme value (about 4.5) for a distant source. The interpretation may be aided by an SF2-SF1 cross plot. If ^{90}Sr is absent, then as the distance between the borehole and the inner edge of a (cylindrically symmetric) ^{137}Cs source increases, the points on the SF2-SF1 cross plot define a "trend line." ^{90}Sr is indicated if the SF2 values are so high that the points on the cross plot lie well above the trend line. However, a ^{90}Sr concentration of about 1,000 pCi/g is necessary to produce a noticeable increase in count rates (Wilson 1997).

2.2.3 Uncertainties of Shape Factor Analysis

The counts resulting from ^{137}Cs and ^{60}Co in the continuum windows are corrected for background by subtracting the counts contributed by the naturally occurring radionuclides ^{40}K, ^{238}U, and ^{232}Th from the continuum windows. Counting statistics for the gamma rays associated with ^{238}U and ^{232}Th are poor for the 100-s counting time typically used by the SGLS in borehole logging; accordingly, there may be a considerable relative statistical uncertainty in the peak intensity that is used to calculate any background correction. To minimize the effects of statistical counting uncertainties in the calculated background corrections, the corrections are calculated at each depth point, then filtered with a Gaussian smoothing function. The correction at a particular depth point is the average over a 5-ft interval that extends 2.5 ft above and 2.5 ft below the point. The other source of experimental uncertainty is systematic uncertainty in the stripping factors. Errors in these constants have been minimized with an heuristic approach, but, in general, the stripping constant errors are the ultimate limitation on the accuracy of the background corrections.

The use of shape factor analysis is currently limited to evaluating the distributions of ^{137}Cs and ^{60}Co and to identifying the presence of ^{90}Sr. At this stage of the method's development, other gamma-ray-emitting radionuclides (i.e., ^{125}Sb, ^{154}Eu, and ^{152}Eu) interfere with shape factor analysis. The number of other radionuclides present in a borehole is a quality indicator. Non-zero values of this indicator may mark intervals of a borehole that are unsuitable for the application of shape factor analysis.

2.3 Log Data and Plots

The results of the processing and analysis of the log data presented in Appendix A, "Spectral Gamma-Ray Logs for Boreholes in the Vicinity of Tank C-110," are grouped into a set of data for each borehole. Each set includes a Log Data Report and log plots showing radionuclide concentration versus depth.

Log plots are presented that show the spatial distribution of the detected man-made radionuclides. Plots of the natural gamma-ray-emitting radionuclides, at the same vertical scale as the man-made contamination plots, allows for interpretation of geologic information and the correlation of these data with the man-made contamination. Rerun sections in selected boreholes are used to check the logging system for data acquisition repeatability.

The log plots show the concentrations of the individual radionuclides or the total gamma count rate in counts per second in each borehole. Where appropriate, log plots show the statistical uncertainties in the calculated concentrations at the 95-percent confidence level (±2 standard deviations).

A combination plot for each borehole shows the individual natural and man-made radionuclide concentrations, the total gamma log, and the Tank Farms gross gamma log. The total gamma log is a plot of the total number of gamma rays detected during each spectrum measurement. The combination plot provides information on the relative contributions of individual radionuclides to the total gamma-ray count. The total gamma log also provides a means for comparing the spectral data with the historical Tank Farms gross gamma log data.

Separate plots showing the results of shape factor analysis of some of the SGLS data are included with each set of borehole plots. The values of CsSF1, CoSF1 (as applicable), SF2, the radionuclide abundance expressed as counts per second, and applicable quality indicators are shown on graphs on these plots. The general expected values for the CsSF1, CoSF1 (as applicable), and SF2 parameters for radionuclides distributed uniformly in the formation or on the outside of the casing are shown on the plots as vertical lines.

The Tank Farms gross gamma log data were collected with a nonspectral logging system previously used by DOE contractors for leak-detection monitoring at the Hanford Tank Farms. This system does not identify specific radionuclides, but its logs provide an important historical record for the individual boreholes and offer a basis for temporal comparison. The gross gamma logs shown on the plots in Appendix A are the latest data available.

Rerun sections in selected boreholes are used to check the logging system for data acquisition repeatability and are provided as separate plots. Radionuclide concentrations shown on these plots are calculated independently from the separate gamma-ray spectra provided by the original and repeated logging runs.

The Log Data Report provides borehole construction information, casing information, logging system identification, and data acquisition parameters used for each log run. A log run is a set of spatially sequential spectra that are recorded in the borehole with the same data acquisition parameters. A single borehole may have several log runs, often occurring on different days because of the length of time required to log the deeper boreholes. The Log Data Report also contains analysis information, including analysis notes and log plot notes.

3.0 Review of Tank History

3.1 C Tank Farm

3.1.1 Construction History

The C Tank Farm is located in the east portion of the 200 East Area, north of 7th Avenue and west of Canton Avenue. This farm was constructed during 1943 and 1944 to store high-level radioactive waste generated by chemical processing of irradiated uranium fuel from C Plant. The tank farm consists of four Type I and twelve Type II single-shell storage tanks. Vadose zone boreholes are located around the tanks for purposes of leak detection. Figure 2 shows the relative positions of the storage tanks and the vadose zone monitoring boreholes around them.

All 16 tanks in the C Tank Farm were constructed to the first-generation tank design and were designed for non-boiling waste with a temperature of less than 220 °F. The twelve Type II tanks are 75 ft in diameter and have capacities of 530,000 gallon (gal) each. The four Type I tanks are 20 ft in diameter and have capacities of 55,000 gal each. Other than diameter, the Types I and II tanks are of the same basic design (Brevick et al. 1994a and 1994b).

The Type II tanks are domed and steel-lined, with a maximum operating depth (cascade overflow level) of approximately 17 ft above the center of the dished tank base; the tank base is 1 ft lower at its center than at its edges. The storage portion of each tank is lined with a 0.25-in.-thick carbon-steel liner. The steel liners on the tank sides extend to 19 ft above the dished bottoms of the tank bases. The interiors of the concrete dome tops are not steel lined, but were treated with a magnesium zincfluosilicate wash. The tanks are entirely below the ground surface and are covered with approximately 7.25 ft of backfill material (Brevick et al. 1994a and 1994b).

The twelve type II tanks are connected in four three-tank cascade series. These cascade series consist of tanks C-101, -102, and -103, C-104, -105, and -106, C-107, -108, and -109, and C-110, -111, and -112. The tanks in the cascade series are arranged with each successive tank sited at an elevation 1 ft lower than the previous tank, creating a gradient allowing fluids to flow from one tank to another as they were filled. The four Type I tanks are connected with tie lines. The tie lines allow the tanks to overflow to other tanks in the series and equalize tank volumes (Brevick et al. 1994a and 1994b).

For primary internal leak detection, tanks C-103, -106, and -107 are each equipped with an ENRAF level detector and tank C-110 is equipped with a manual tape. Tanks C-101, -102, -104, -105, -108, -109, -111, -112, -201, -202, -203, and -204 are not equipped with primary leak-detection sources (Hanlon 1997).

3.1.2 Geologic and Hydrologic Setting

Excavation for the construction of the C Tank Farm occurred in glaciofluvial sediments of the Hanford formation. These sediments consist primarily of cobbles, pebbles, and coarse to

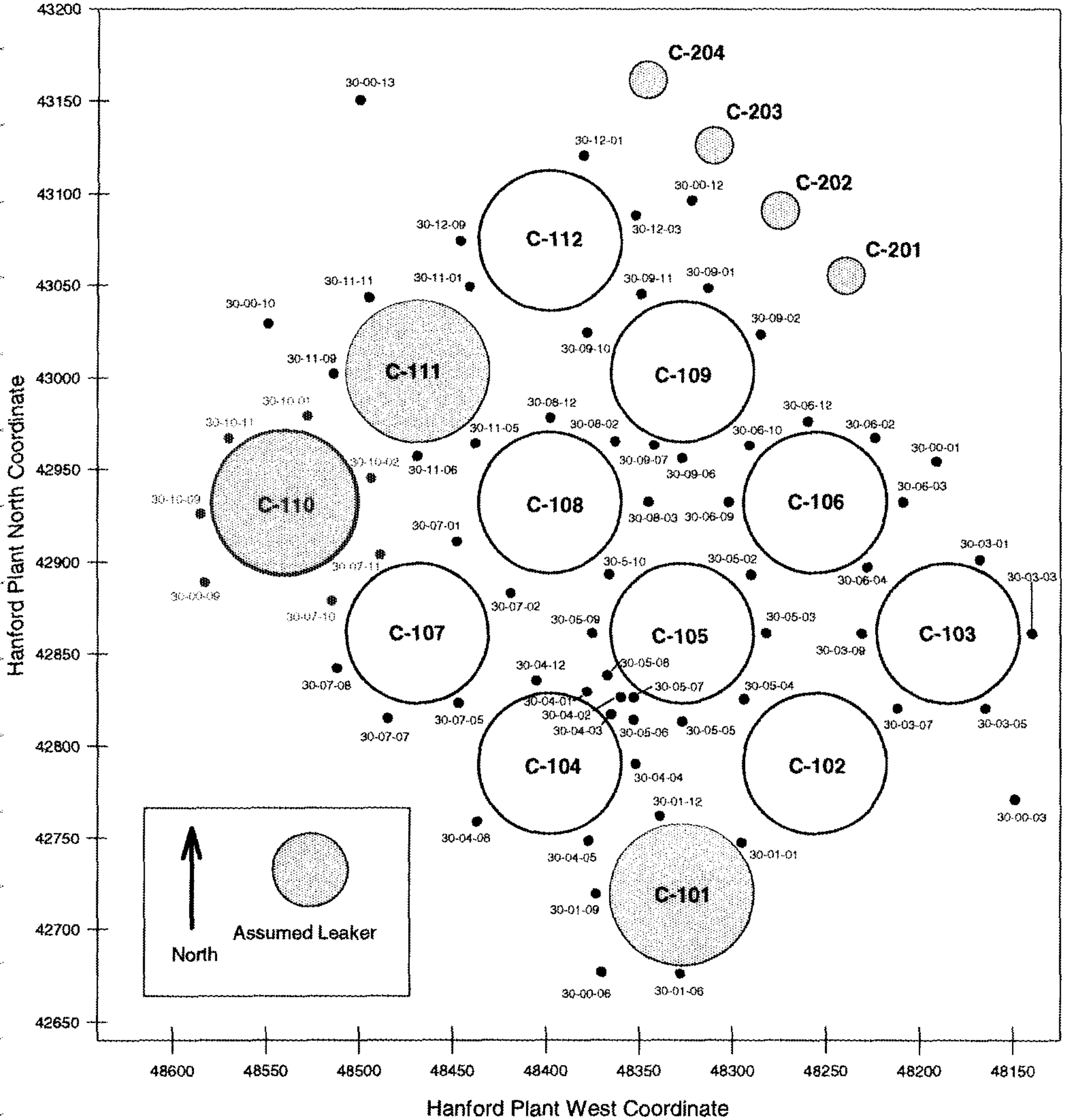

Figure 2. Plan View of Tanks and Boreholes in the C Tank Farm

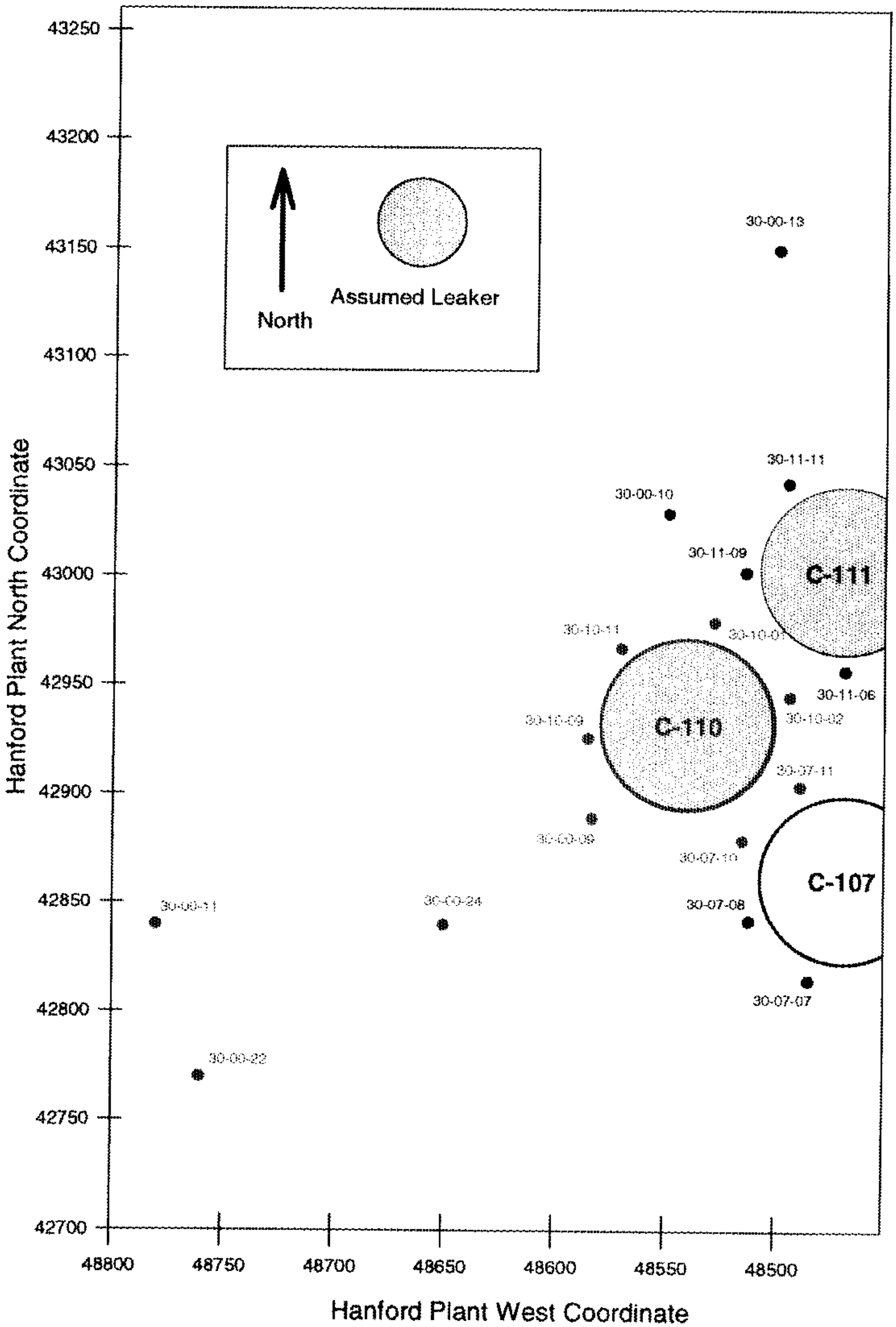

Figure 2 (continued). Plan View of Tanks and Boreholes in the C Tank Farm medium sands with some silts. The excavated sediments were used as backfill around the completed tanks (Price and Fecht 1976).

Beneath the backfill material are the undisturbed sediments of the Hanford formation. The Hanford formation sediments consist of pebble to boulder gravel, fine- to coarse-grained sand, and silt. Three distinct facies were recognized by Lindsey (1992): gravel-dominated, sand-dominated, and silt-dominated (ordered from top to bottom of the formation). Baker et al. (1991) named these facies the coarse-grained deposits (generally referred to as the Pasco Gravels), the plane-laminated sand facies, and the rhythmite facies (commonly referred to as the Touchet Beds), respectively. The Hanford formation sediments extend to a depth of about 225 ft in the vicinity of the C Tank Farm (Lindsey 1993).

The distribution and similarities in lithologic succession of the facies types described above indicate the Hanford formation can be divided into three stratigraphic sequences across the 200 East Area. These sequences are designated: 1) upper gravel, 2) sandy, and 3) lower gravel. The sequences are composed mostly of the gravel-dominated and sand-dominated facies. The silt-dominated facies are relatively rare except in the southern part of the 200 East Area. Because of the variability of Hanford deposits, contacts between the sequences can be difficult to identify (DOE 1993).

In the vicinity of the C Tank Farm, the upper gravel sequence is dominated by deposits typical of the gravel-dominated facies of the Hanford formation. Lesser occurrences of the sand-dominated facies are encountered locally (DOE 1993). The upper gravel sequence consists of well-stratified gravels with lenticular sand and silt interbeds and extends to a depth of approximately 61 to 73 ft (23 to 35 ft below the base of the tank farm excavation). Strata within this interval generally dip to the east-southeast and thin to the south (Lindsey 1993). However, strata near the transition from the gravel-dominated to the sand-dominated facies locally dip to the north and east (Price and Fecht 1976).

The sandy sequence generally consists of deposits typical of the sand-dominated facies of the Hanford formation (DOE 1993). The sandy sequence is characterized by well-stratified coarse- to medium-grained sand with minor pebble and lenticular silt interbeds less than 1 ft thick. Localized silty intervals greater than 1 ft thick may be present and could potentially host perched water horizons that would probably not be laterally extensive because of pinchouts and clastic dikes. The sandy sequence extends to a depth of approximately 198 ft (Lindsey 1993).

The lower gravel sequence of the Hanford formation is dominated by deposits typical of the gravel-dominated facies. Local intercalated intervals of the sand-dominated facies are also found (DOE 1993). This unit is composed of interbedded sands and gravels with few silt interbeds. Perched water is considered unlikely in this unit. The lower gravel sequence is about 27 ft thick and extends to a depth of approximately 225 ft (Lindsey 1993).

The Ringold Formation directly underlies the Hanford formation in the vicinity of the C Tank Farm. The Ringold Formation is approximately 70 ft thick and extends to a depth of 295 ft. A thin, discontinuous silt-rich layer that dips to the south and pinches out to the north and west is present in the southern portion of the tank farm. Perched water may occur at the top of this unit. A variably cemented pebble to cobble gravel with a sand matrix occurs stratigraphically below the silt-rich layer. This gravel may contain mud interbeds that could cause perched water to form if the mud is cemented or well enough developed (Lindsey 1993).

In the vicinity of the C Tank Farm, the uppermost aquifer occurs within the Ringold Lower Mud Unit at a depth of approximately 245 ft (Lindsey 1993; PNNL 1997). This uppermost aquifer is generally referred to as the unconfined aquifer, but includes locally confined to semi-confined areas DOE 1993).

The Ringold Formation is underlain by the Columbia River Basalt Group, which includes approximately 50 basalt flows. Sandwiched between the various basalt flows are sedimentary interbeds, collectively called the Ellensberg Formation. The Ellensberg Formation consists of mud, sand, and gravel deposited between volcanic eruptions. These sediments and porous flow tops and bottoms form confined aquifers that extend across the Pasco Basin (PNNL 1997).

At the Hanford Site, recharge of the unconfined aquifer by precipitation is highly variable depending on climate, vegetation, and soil texture. Recharge from precipitation is highest in coarse-textured soils with little or no vegetation (PNNL 1997). Fayer and Walters (1995) estimate that recharge to the unconfined aquifer in the area of the C Tank Farm is approximately 2 to 4 in. per year.

For more detailed information about the geology and hydrogeology below the C Tank Farm, the reader is referred to the following documents: Price and Fecht (1976), Caggiano and Goodwin (1991), Lindsey (1993), Lindsey (1995), and PNNL (1997).

3.1.3 Tank Contents

The C Tank Farm received a variety of waste types beginning in 1945. Initially, tanks C-101, -102, -103, -104, -105, and -106 received metal waste, and tanks C-107, -108, -109, -110, -111, and -112 received byproduct cake solution and waste solution from the first decontamination waste cycle (referred to collectively as first-cycle waste). Tanks C-201, -202, -203, and -204 were used to settle waste to allow the supernatant liquid to be sent to a crib (Brevick et al. 1994b). Over their operating life, the C Tank Farm tanks also received B Plant decontamination waste, U Plant waste, cladding wastes, PUREX Plant fission product waste, waste water, and other waste types (Agnew 1997). A large amount of strontium from the PUREX Plant fission product waste remains in tank C-106 and has caused a high heat load in the tank (Brevick et al. 1994b).

The tanks in the C Tank Farm currently contain an estimated 1,976,000 gal of mixed wastes (Hanlon 1997) consisting primarily of various cladding wastes, tributyl phosphate and uranium recovery wastes, and sludge produced by in-tank scavenging (Agnew 1997). Detailed descriptions of the waste streams are presented in Anderson (1990) and Agnew (1995, 1997). On the basis of information presented in Agnew (1997), some of the principal radionuclides in the tank wastes include ^{90}Sr, ^{137}Cs, ^{144}Ce, ^{151}Sm, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{63}Ni, ^{137m}Ba, ^{155}Eu, and ^{154}Eu.

The wastes currently contained in the C Tank Farm tanks are in the form of sludge, supernatant liquid, and interstitial liquid. Sludge is composed of a solid precipitate (hydrous metal oxides) that results from the neutralization of acid waste. The wastes were neutralized before being transferred to the tanks. Sludge forms the "solids" component of the tank waste. Liquids are present as supernatant and interstitial liquids. Supernatant liquid floats on the surface of the solid waste and interstitial liquid fills the interstitial voids within the solid waste. Interstitial liquid may be drainable if it is not held in the interstitial voids by capillary forces.

3.1.4 Tank Farm Status

All the tanks in the C Tank Farm were removed from service during the late 1970s and early 1980s (Brevick et al. 1994a). Nine tanks in the C Tank Farm are categorized as sound (C-102, -103, -104, -105, -106, -107, -108, -109, and -112), and seven are categorized as assumed leakers (C-101, -110, -111, -201, -202, -203, and -204) (Hanlon 1997). The tanks in the C Tank Farm that have been designated as "assumed leakers" are identified on Figure 2.

All the tanks in the C Tank Farm, except tanks C-103 and C-106, have been interim stabilized, and all the tanks, except tanks C-103, -105, and -106, have intrusion prevention completed. Tanks C-103, -105, and -106 have been partial interim isolated (Hanlon 1997).

Currently, tanks C-102 and C-103 are on the Organics Watch List and tank C-106 is on the High-Heat Load Watch List (Hanlon 1997). SSTs are added to a watch list because the waste in the tanks may be in a potentially unsafe condition and the handling of the waste material requires corrective action or special monitoring to reduce or eliminate the hazard. Resolution of the safety issues has been codified under Public Law 101-510 (generally known as the Wyden Amendment).

3.2 Tank C-110

Tank C-110 was constructed during 1943 and 1944 (Welty 1988). This tank is the first tank in a three-tank cascade series; the tank cascaded waste to tanks C-111 and C-112 from 1946 until 1947. The tank received first-cycle waste from the second quarter of 1946 until the third quarter of 1952. Waste was pumped out of the tank during the third quarter of 1952, and the overflow outlet to tank C-111 was plugged in November 1952 (Brevick et al. 1994a).

Tank C-110 received uranium recovery waste from the fourth quarter of 1952 until the first quarter of 1953. During the first quarter of 1956, the waste was transferred from the tank to the CR Vault. The tank received organic wash waste during the second quarter of 1956 and contained this waste until the first quarter of 1970. The tank also received first-cycle waste from the first quarter of 1957 until the first quarter of 1969. On the basis of information presented in Brevick et al. (1994a), the tank was apparently pumped in 1970. Tank C-110 received ion-exchange waste and evaporator bottoms from the second quarter of 1970 until the fourth quarter of 1972. Between the first quarter of 1972 and the first quarter of 1976, the tank received coating waste, organic wash waste, evaporator bottoms, and ion-exchange waste.

The tank was removed from service in 1976 and was classified as "questionable integrity" in 1977 on the basis of anomalously high gamma-ray activity in boreholes 30-10-02 and 30-10-09 (Welty 1988; Brevick et al. 1994a). A salt-well pump was installed in March 1976 and salt-well pumping was completed in March 1979 (Welty 1988). The tank was primary stabilized in September 1979, and partial isolation was completed in December 1982. The tank's classification was changed to "assumed leaker" in 1984 with an estimated leak volume of 2,000 gal (Brevick et al. 1994a). Documentation of the leak volume estimate was not found.

The liquid level in tank C-110 increased slowly from September 1978 (when the liquid-level baseline was established) until June 1986, when the 2-in.-increase criteria was reached (Anderson 1986). The liquid-level increase was confirmed by in-tank photographs and was attributed to intrusions (Welty 1988). A study was conducted to determine the source of the intrusion; the study resulted in a recommendation to eliminate areas where water tended to pond at the ground surface above the tank (Groth 1987). There was no information available to indicate whether the recommended modifications were made.

Liquid-level baseline adjustments were made in December 1984 and May 1985. The tank was salt-well pumped again in November 1991, and another liquid-level baseline adjustment was made in January 1992 (Brevick et al. 1994a).

The present inventory for tank C-110 includes 177,000 gal of sludge and 1,000 gal of supernatant liquid classified as dilute-complexed waste. The 177,000 gal of sludge is estimated to include 28,000 gal of drainable, interstitial liquid (Hanlon 1997). The waste level is approximately 63 in. above the dished bottom of the tank base (Brevick et al. 1994b).

The primary method of leak detection for tank C-110 is a manual tape (Hanlon 1997).

4.0 Boreholes in the Vicinity of Tank C-110

Ten vadose zone monitoring boreholes surround tank C-110. These boreholes are 30-10-01, 30-10-02, 30-07-11, 30-07-10, 30-00-22, 30-00-24, 30-00-11, 30-00-09, 30-10-09, and 30-10-11. Figure 2 shows the locations of these boreholes in red.

All the boreholes, except boreholes 30-00-09, 30-00-22, 30-00-24, and 30-00-11 were completed with 6-in. steel casings. The surface exposures of most the borehole casings are flush with small-diameter concrete pads, making accurate measurements of the borehole casing wall thicknesses difficult. Because the calculations of radionuclide concentrations incorporate a correction factor based on casing thickness, correction factors appropriate to the casing thickness must be determined and applied in the development of the log data. The casing thickness for the 6-in. boreholes is assumed to be 0.280 in., on the basis of the published thickness for schedule-40, 6-in. carbon-steel casing, which was the typical casing used in tank farm borehole construction in the 1970s.

A driller's log was not available to provide construction details for borehole 30-00-09. However, based on the date of construction, the borehole's location, information presented in Chamness and Merz (1993), and the construction details observed in the field, the borehole is assumed to be constructed similarly to boreholes 30-00-03 and 30-00-06. Borehole 30-00-09 was apparently completed with 8-in. and 12-in. casings to a depth of about 55 ft and with only 8-in. casing below this depth. An appropriate correction factor was not available to account for the attenuation caused by the double casing and any grout, soil, or open space between the two casings; therefore, a correction factor for the 8-in. casing was applied to data acquired throughout the entire borehole. A correction factor for 0.330-in. casing was applied to the 8-in. casing because it most closely matches the actual casing thickness of 0.313 in. The use of this correction factor will cause the calculated concentrations for radionuclides above about 55 ft to be underestimated and below about 55 ft to be slightly overestimated. Concentration values for the interval above about 55 ft are highly inaccurate and should be used only as qualitative indicators of contaminant presence, lithology changes, and casing locations.

Drilling logs were not available to provide construction details for boreholes 30-00-11, 30-00-22, and 30-00-24. However, on the basis of information presented in Chamness and Merz (1993), all three boreholes were constructed in March 1977 and completed to depths of 60 ft with 6-in. grouted casing. However, an appropriate correction factor was not available to account for the attenuation caused by the grout. The attenuation caused by the grout will cause the calculated concentrations for radionuclides to be underestimated. Calculated concentrations for these three boreholes should be considered inaccurate and should be used only as qualitative indicators of contaminant presence, lithology changes, and casing locations.

Spectral gamma-ray data were acquired for each borehole. The spectral gamma-ray data were collected in the move/stop/acquire logging mode with a 100-s acquisition time at 0.5-ft depth intervals. All the boreholes were logged dry.

The pre- and post-survey field verification spectra were used to create the peak resolution and channel-to-energy parameters used in processing the spectra acquired during logging operations.

The following sections present results of the spectral gamma-ray log data collected from these boreholes. Appendix A contains the plots of the log data. The most recent historical gross gamma data are presented on the combination plots in Appendix A. These data, shape factor analysis results, historical gross gamma logs from 1975 to 1994, and results from other investigations were used in the preparation of this report.

4.1 Borehole 30-10-01

Borehole 30-10-01 is located approximately 7 ft from the north side of tank C-110 and was given the Hanford Site designation 299-E27-101. This borehole was drilled in September 1974 and completed to a depth of 100 ft with 6-in. casing. A driller's log was not available for this borehole; therefore, information from Chamness and Merz (1993) was used to prepare this report. No data information that the borehole was grouted or that the casing was perforated;

therefore, it is assumed that the borehole was not grouted or perforated. Total logging depth achieved by the SGLS was 100.0 ft.

The only man-made radionuclide detected in this borehole was ^{137}Cs. ^{137}Cs contamination was detected continuously from the ground surface to 2.5 ft, continuously from 6.5 to 16.5 ft, and at 19.5 ft. The maximum measured ^{137}Cs concentration was about 2.5 pCi/g at 1 ft. A higher concentration (8.9 pCi/g) was detected at the ground surface; however, as described in Section 2.1, this is not an accurate concentration value because the source-to-detector geometry at the top of the borehole differs from the source-to-detector geometry used in the calibration.

The logs of the naturally occurring radionuclides show an increase in the background ^{40}K concentrations from about 13 to 16.5 pCi/g at 38 ft. This concentration increase is probably caused by a change from backfill material to the undisturbed sediments of the Hanford formation at about this depth.

^{40}K concentrations are slightly increased from about 50 to 54 ft and remain slightly elevated to a background concentration of about 16 pCi/g below 54 ft. The concentration increase at about 50 ft may be caused by a change from the gravel-dominated to the sand-dominated facies of the Hanford formation.

^{232}Th concentrations increase sharply in the interval from 76 to 79 ft. This concentration increase is reflected on the total gamma log plot.

The SGLS total gamma-ray plot reflects the influence of the natural and man-made radionuclides. The ^{137}Cs concentrations from the ground surface to 17 ft and the ^{40}K concentrations below 38 ft are clearly reflected on the total gamma-ray plot.

A shape factor analysis of the distribution of gamma-ray energies was performed for this borehole and a plot of the analysis results is included in Appendix A. The shape factor analysis indicates that the ^{137}Cs contamination from 8 to 9 ft is uniformly distributed in the formation around the borehole. The indicated distribution is consistent with the contaminant distribution that would be expected from a surface spill that migrated into the backfill material around the borehole at 8 to 9 ft.

Gross gamma logs from January 1975 through March 1994 were reviewed. No zones of anomalous gamma-ray activity were identified.

The ^{137}Cs contamination from the ground surface to 19.5 ft appears to be the result of a surface spill where contamination migrated down into the backfill material around the tank.

4.2 Borehole 30-10-02

Borehole 30-10-02 is located approximately 6 ft from the northeast side of tank C-110 and was given the Hanford Site designation 299-E27-102. This borehole was drilled in September 1974 and completed to a depth of 100 ft with 6-in. casing. A driller's log was not available for this borehole; therefore, information from Chamness and Merz (1993) was used to prepare this report. No information indicated that the borehole was grouted or that the casing was perforated; therefore, it is assumed that the borehole was not grouted or perforated. Total logging depth achieved by the SGLS was 99.0 ft.

The only man-made radionuclide detected in this borehole was ^{137}Cs. ^{137}Cs contamination was detected continuously from the ground surface to 30.5 ft, at 32.5 ft, continuously from 34 to 37 ft, and continuously from 44 to 63.5 ft. The maximum measured ^{137}Cs concentration was about 16.5 pCi/g at 47 ft. A higher concentration (20.2 pCi/g) was detected at the ground surface; however, as described in Section 2.1, this is not an accurate concentration value because the source-to-detector geometry at the top of the borehole differs from the source-to-detector geometry used in the calibration.

The logs of the naturally occurring radionuclides show an increase in ^{40}K background concentrations from about 13 to 15 pCi/g at 38 ft. This concentration increase is probably caused by a change from backfill material to the undisturbed sediments of the Hanford formation at about this depth.

^{40}K concentrations are slightly increased below about 49 ft and remain slightly elevated to a background concentration of about 16 pCi/g below 49 ft. This increase in ^{40}K concentrations at about 49 ft may be caused by a change from the gravel-dominated to the sand-dominated facies of the Hanford formation.

The SGLS total gamma-ray plot reflects the influence of the natural and man-made radionuclides. The ^{137}Cs concentrations from the ground surface to 63.5 ft and the KUT concentration changes from about 80 to 92 ft are clearly reflected on the total gamma-ray plot.

The interval between 20 and 40 ft was relogged as an additional quality check and to demonstrate the repeatability of the radionuclide concentration measurements made by the SGLS. A comparison of the measured concentrations of the naturally occurring and man-made radionuclides using the data sets provided by the original and repeated logging runs is included with Appendix A. The measurements generally repeat within two standard deviations (95-percent confidence level), indicating the excellent repeatability of the measured spectral gamma-ray intensities used to calculate the radionuclide assays.

A shape factor analysis of the distribution of gamma-ray energies was performed for this borehole, and a plot of the analysis results is included in Appendix A. The analysis indicates that the ^{137}Cs contamination from about 2 to 7 ft is uniformly distributed in the backfill material around the borehole. The distribution of the ^{137}Cs contamination from about 7 to 30 ft appears to vary from uniform in the backfill material, to non-uniformly distributed in the backfill material, to on the borehole casing. The shape factor analysis indicates that the ^{137}Cs contamination from 44 to 63.5 ft is distributed in the formation around the borehole, but that it is not uniformly distributed. The distribution is consistent with a subsurface plume that was intercepted by the borehole.

Gross gamma logs from January 1975 through March 1994 were reviewed, and a plot of selected logs from 1975 to 1983 is included in Appendix A. Zones of anomalously high gamma-ray activity are present from the ground surface to about 30 ft and about 45 to 64 ft in the earliest gross gamma-ray logs available. This record indicates that the ^{137}Cs contamination was probably present in these intervals by January 1974. In addition, Welty (1988) indicates that anomalously high gamma-ray activity was present at 47 ft when the borehole was first logged in September 1974. Because of this anomalous gamma-ray activity, as well as the activity detected in borehole 30-10-09, tank C-110 was declared questionable integrity in 1977 and an assumed leaker in 1984 (Welty 1988).

The ^{137}Cs contamination from the ground surface to about 37 ft is probably the result of a surface spill. Contamination probably migrated down into the backfill material to a depth of 37 ft.

The ^{137}Cs contamination from 44 to 63.5 ft probably resulted from a tank or pipeline leak. As noted previously, the earliest historical gross gamma logs available (January 1975) indicate that anomalously high gamma activity was present in this interval by 1975; Welty (1988) indicates that anomalously high gamma activity was present in this interval by September 1974.

The ^{137}Cs contamination at the bottom of the borehole may be from particles that were blown down into the borehole.

4.3 Borehole 30-07-11

Borehole 30-07-11 is located approximately 17 ft from the southeast side of tank C-110 and was given the Hanford Site designation 299-E27-93. This borehole was drilled in July 1974 and completed to a depth of 100 ft with 6-in. casing. A driller's log was not available for this borehole; therefore, information from Chamness and Merz (1993) was used to prepare this report. No information indicated that the borehole was grouted or that the casing was perforated; therefore, it is assumed that the borehole was not grouted or perforated. Total logging depth achieved by the SGLS was 97.5 ft.

The man-made radionuclides detected in this borehole were ^{137}Cs, ^{60}Co, and ^{154}Eu. ^{137}Cs contamination was detected almost continuously from the ground surface to 19 ft, intermittently from 20.5 to 36 ft, almost continuously from 49 to 74.5 ft, and at 97.5 ft. ^{60}Co contamination was detected at 4 ft, and ^{154}Eu contamination was detected at 0.5, 1, and 4 ft. Maximum concentrations of these contaminants could not be determined because of the high dead time from 1.5 to 3.5 ft.

^{40}K concentrations are relatively elevated from 38 to 40 ft (the approximate base of the tank farm excavation). This concentration increase probably represents a change from backfill material to the undisturbed sediments of the Hanford formation. KUT concentrations are higher below about 49 ft. This increase in KUT concentrations may represent the contact between the gravel- and sand-dominated facies of the Hanford formation.

Historical gross gamma logs from January 1975 through June 1994 were reviewed, and the only interval of anomalously high gamma-ray activity noted was near the ground surface. An investigation into the cause of this anomalous gamma-ray activity was conducted in late 1992 (Winkler 1992). The source of the activity was attributed to salt-well transfer lines that pass close by borehole 30-07-11 at a depth of about 3 ft. The transfer lines were used immediately before a 1992 increase was detected, and flushing of the salt-well transfer line with clean water resulted in an activity decrease in the borehole. Additionally, soil sampling was conducted around the tank. It was concluded that the salt-well transfer line was not properly designed, allowing material to remain in the line after a transfer (Winkler 1992). The ^{137}Cs, ^{60}Co, and ^{154}Eu contamination from 1 to 4 ft is probably from material remaining within the transfer line.

A shape factor analysis of the distribution of gamma-ray energies was performed for this borehole, and a plot of the analysis results is included in Appendix A. Because of high dead times and the streaming of gamma rays from the high-concentration interval in the upper 5 ft of the borehole, shape factor analysis could not be used at depths above about 8 ft. In addition, ^{137}Cs concentrations from depths below about 14 ft are too low to allow shape factor analysis to be performed. The analysis indicates that the ^{137}Cs contamination from about 8 to 14 ft is nearly uniformly distributed in the backfill material around the borehole. The indicated distributions are consistent with the contaminant distribution that would be expected from a surface spill that migrated downward into the backfill material around the borehole.

The ^{137}Cs contamination from the ground surface to 16 ft is probably the result of one or more surface spills that migrated into the backfill material and from material contained in the salt-well transfer line near the borehole. The ^{137}Cs contamination from 16.5 to 37 ft may have been carried down during borehole drilling or may have migrated down the outside of the borehole casing. The ^{137}Cs contamination from 49 to 74.5 ft is probably the result of a tank or pipeline leak. The source of the leak could be a number of tanks and their associated piping in the vicinity of tank C-110, including tank C-110 itself.

The ^{137}Cs contamination near the bottom of the borehole may be the remnant of a plume that existed at this depth, or the contamination may have migrated down the inside or outside of the borehole casing to this depth.

4.4 Borehole 30-07-10

Borehole 30-07-10 is located approximately 17 ft from the southeast side of tank C-110 and was given the Hanford Site designation 299-E27-92. This borehole was drilled in September 1974 and completed to a depth of 100 ft with 6-in. casing. A driller's log was not available for this borehole; therefore, information from Chamness and Merz (1993) was used to prepare this report. No information indicated that the borehole was grouted or that the casing was perforated; therefore, it is assumed that the borehole was not grouted or perforated. Total logging depth achieved by the SGLS was 98.5 ft.

The only man-made radionuclide detected in this borehole was ^{137}Cs. ^{137}Cs contamination was detected almost continuously from the ground surface to 24 ft, 36 to 37 ft, and at 26, 26.5, and 77.5 ft. The maximum ^{137}Cs concentration was 3 pCi/g at 1 ft.

^{40}K and ^{232}Th concentrations increase at 39.5 ft (the approximate base of the tank farm excavation). These concentration increases probably represent a change from backfill material to the undisturbed sediments of the Hanford formation. ^{40}K concentrations are relatively decreased from 42 to about 45 ft, which may represent an increase in the percentage of coarse-grained material, such as gravel, in this interval. The increase in the ^{40}K concentrations at about 45 ft probably represents the contact between the gravel- and sand-dominated facies of the Hanford formation.

The interval between 20 and 40 ft was relogged as an additional quality check and to demonstrate the repeatability of the radionuclide concentration measurements made by the SGLS. A comparison of the measured ^{137}Cs concentrations and the naturally occurring radionuclides using the data sets provided by the original and repeated logging runs is included in Appendix A. The measurements repeat within two standard deviations (95-percent confidence level), indicating excellent repeatability of the measured gamma-ray spectral peak intensities used to calculate the radionuclide assays.

A shape factor analysis of the distribution of gamma-ray energies was performed for this borehole, and a plot of the analysis results is included in Appendix A. The analysis indicates that the distribution of ^{137}Cs contamination from the ground surface to about 22 ft varies from remote to the borehole casing, to uniformly distributed in the vadose material around the borehole, to near the borehole casing. The indicated distribution is consistent with a contaminant distribution that would be expected from one or more surface spills that migrated into the backfill material near the borehole. ^{137}Cs concentrations at depths below about 22 ft were too low to perform shape factor analysis.

Historical gross gamma logs from January 1975 through June 1994 were reviewed. No zones of anomalous gamma-ray activity were identified in the logs.

The ^{137}Cs contamination from the ground surface to 26.5 ft is probably the result of one or more surface spills that migrated into the backfill material around the borehole. The ^{137}Cs contamination from 36 to 37 ft may have accumulated at the base of the tank farm excavation from a tank or pipeline leak. The source of the leak could be a number of tanks and their associated piping in the vicinity of tank C-110, including tank C-110 itself.

The ^{137}Cs contamination at 77.5 ft may have been carried down during drilling operations.

4.5 Borehole 30-00-09

Borehole 30-00-09 is located approximately 19 ft from the southwest side of tank C-110 and was given the Hanford Site designation 299-E27-57. This borehole was drilled in December 1944 and completed to a depth of 150 ft with 8-in. casing. A driller's log was not available for this borehole; however, based on the date of construction, the borehole location, information presented in Chamness and Merz (1993), and the construction details from the field, it is believed that this borehole was constructed similarly to boreholes 30-00-03 and 30-00-06. In boreholes 30-00-03 and 30-00-06, a string of 12-in. surface casing is present from just below the ground surface to a depth of 54 to 58 ft. Data from the double-cased portion of the borehole are usable only for qualitative interpretations because of this double casing. In addition, the 8-in. casing in boreholes 30-00-03 and 30-00-06 is perforated from just below the bottom of the surface casing (about 54 to 58 ft) to the bottom of the borehole, and the bottom 8-in. of the casing is grouted.

The depth of the borehole was measured at 58 ft with an electrical tape before borehole logging, rather than 150 ft as reported on the driller's log. The reason the borehole is more shallow than reported in the driller's log is not known. Total logging depth achieved by the SGLS was 57.5 ft.

The zero reference for logging is the top of the 8-in. casing. The borehole is located on a hillside, and the top of the 8-in. casing is approximately 1 ft above the surface of the slope and about 11 ft above the tank farm ground surface. The top 1 ft of the borehole was not logged. The 12-in. casing is not visible at the ground surface, and it is possible that an additional section of 8-in. casing was added to the top of the original borehole casing to extend the top of the casing above the hill slope.

An appropriate casing correction factor is not available to account for the effects of the double casing present in the borehole. A 0.330-in. casing correction factor was used for the 8-in. casing rather than the actual casing thickness of 0.313 in. A casing correction factor for 0.313 in. is not available, and the correction factor for 0.330-in. casing is the closest available. Use of the correction factor for 0.330-in. casing will cause calculated radionuclide concentrations to be underestimated for the double-cased portion of the borehole.

The only man-made radionuclide detected in this borehole was ^{137}Cs. ^{137}Cs contamination was detected from 1 to 3 ft. The concentrations measured in this interval are not accurate because this portion of the borehole is within the slope of the hillside, and the source-to-detector configuration does not match the configuration used in system calibration.

KUT concentrations decrease below a depth of 4 ft. This concentration decrease is probably caused by the top of the 12-in. surface casing located at this depth.

^{40}K concentrations increase below about 42 ft. This concentration increase may indicate an increase in the silt or sand fraction of sediments of the Hanford formation at about this depth. The increase in ^{40}K concentrations detected at this depth does not seem sufficient to mark the bottom of the double-cased portion of the borehole on the basis of the concentration increases calculated at the bottom of the double-cased portions of boreholes 30-00-03 and 30-00-06. ^{40}K concentrations decrease sharply at about 57 ft. This ^{40}K concentration decrease probably indicates the presence of a casing shoe in this interval, marking the bottom of the 12-in. casing.

A shape factor analysis of the distribution of gamma-ray energies was not performed for this borehole because of the presence of double casing. The presence of an additional casing causes additional attenuation of the gamma rays beyond that which would be caused by vadose zone material, rendering the modeling upon which interpretation of shape factor analysis results is based inapplicable to this borehole.

Historical gross gamma-ray logs from January 1975 through October 1993 were reviewed. No zones of anomalous gamma-ray activity were identified in logs for this time interval.

The near-surface ^{137}Cs contamination is probably from surface contamination that was detected through the casing above the ground surface.

4.6 Borehole 30-10-09

Borehole 30-10-09 is located approximately 5 ft from the west side of tank C-110 and was given the Hanford Site designation 299-E27-103. This borehole was drilled in September 1974 and completed to a depth of 100 ft with 6-in. casing. A driller's log was not available for this borehole; therefore, information from Chamness and Merz (1993) was used to prepare this report. No information indicated that the borehole was grouted or that the casing was perforated; therefore, it is assumed that the borehole was not grouted or perforated. Total logging depth achieved by the SGLS was 97.5 ft.

The only man-made radionuclide detected in this borehole was ^{137}Cs. ^{137}Cs contamination was measured intermittently from the ground surface to 13.5 ft and almost continuously from 17 to 37.5 ft. A maximum ^{137}Cs concentration of 0.6 pCi/g was detected at 34 ft. A higher concentration (7.9 pCi/g) was detected at the ground surface; however, the ^{137}Cs concentration calculated at the ground surface is not an accurate concentration because the source-to-detector geometry at the top of the borehole differs from the source-to-detector geometry used in the calibration.

^{40}K concentrations sharply increase to a concentration of about 18 pCi/g from 41 to 42 ft. ^{40}K concentrations are about 18 pCi/g from 42 to about 51 ft and then decrease to about 16 pCi/g at about 51 ft. The concentration increase at 41 ft may mark the change from backfill material above this depth to the undisturbed sediments of the Hanford formation below. The elevated ^{40}K concentrations from 42 to 51 ft are probably caused by the presence of fine-grained sediments of the Hanford formation in this interval.

The SGLS total gamma-ray plot reflects the influence of the natural and man-made radionuclides. The elevated ^{40}K concentrations from 41 to 51 ft are clearly reflected on the total gamma-ray plot.

A shape factor analysis of the distribution of gamma-ray energies was performed for this borehole. Concentrations of contaminants were too low, except at the ground surface, to allow shape factors to be calculated for this borehole. Because the radionuclide concentrations calculated at the ground surface are not accurate, no useful information was provided by the shape factor analysis for this borehole.

Historical gross gamma logs from January 1975 through March 1994 were reviewed, and a plot of selected logs from 1975 to 1983 is included in Appendix A. A zone of anomalous gamma-ray activity was present from about 43 to 60 ft by January 1975. In addition, Welty (1988) indicates that anomalously high gamma-ray activity was present in this interval when the borehole was first logged in October 1974. The anomalous gross gamma-ray activity from about 43 to 60 ft appears to have decreased to background levels by 1980. Based on the apparent decay rate noted in the historical logs from January 1975 through January 1978, the contaminant responsible for this activity may have been ^{106}Ru, which has now decayed away. Because of this anomalous gamma-ray activity, as well as the activity detected in borehole 30-10-02, tank C-110 was declared an assumed leaker in 1984 (Welty 1988).

The ^{137}Cs contamination in the upper 37.5 ft of the borehole is probably the result of a surface spill that migrated into the backfill material around the borehole. The ^{137}Cs contamination could also have migrated down the outside of the borehole casing or could have been carried down during drilling operations. The anomalous gamma-ray activity detected in 1975 from about 43 to 60 ft may have been the result of a tank leak as concluded at that time.

4.7 Borehole 30-10-11

Borehole 30-10-11 is located approximately 5 ft from the northwest side of tank C-110 and was given the Hanford Site designation 299-E27-104. This borehole was drilled in April 1975 and completed to a depth of 100 ft with 6-in. casing. A driller's log was not available for this borehole; therefore, information from Chamness and Merz (1993) was used to prepare this report. No information indicated that the borehole was grouted or that the casing was perforated; therefore, it is assumed that the borehole was not grouted or perforated. Total logging depth achieved by the SGLS was 98.5 ft.

The only man-made radionuclide detected in this borehole was ^{137}Cs. ^{137}Cs contamination was measured continuously from the ground surface to 3.5 ft. A maximum ^{137}Cs concentration of 6.1 pCi/g was detected at 1 ft.

^{40}K and ^{232}Th concentrations increase at about 43.5 ft. These concentration increases are probably from an increase in fine-grained sediments in the Hanford formation at this depth.

The SGLS total gamma-ray plot reflects the influence of the natural and man-made radionuclides. The elevated ^{40}K and ^{232}Th concentrations from 43.5 to 58.5 ft are clearly reflected on the total gamma-ray plot.

A shape factor analysis of the distribution of gamma-ray energies was performed for this borehole, and a plot of the analysis results is included in Appendix A. The analysis indicates that the ^{137}Cs contamination from 1 to 3 ft is uniformly distributed in the backfill material around the borehole. The indicated distributions are consistent with the contaminant distribution that would be expected from a surface spill that migrated into the backfill material around the borehole.

Historical gross gamma logs from January 1975 through June 1994 were reviewed. No zones of anomalous gamma-ray activity were identified in the logs.

The ^{137}Cs contamination detected in the upper 3.5 ft of the borehole is probably the result of a surface spill that migrated into the backfill material around this borehole.

4.8 Borehole 30-00-22

Borehole 30-00-22 is located approximately 247 ft from the southwest side of tank C-110 and was given the Hanford Site designation 299-E27-120. This borehole is not located near tank C-110, but is included in this TSDR for reporting purposes. This borehole was drilled in March 1977 and completed to a depth of 60 ft with 6-in. casing. A driller's log was not available for this borehole; therefore, information from Chamness and Merz (1993) was used to prepare this report. Chamness and Merz (1993) indicate that the borehole was grouted, but do not note perforations. It is therefore assumed that the borehole casing was not perforated.

The upper 1 ft of the borehole was not logged because the top 1 ft of casing was above the ground surface. The total logging depth achieved by the SGLS was 54.0 ft.

The only man-made radionuclide detected in this borehole was ^{137}Cs. ^{137}Cs contamination was detected almost continuously from the ground surface to 18 ft. A well-defined peak occurs at about 6 to 10 ft with a maximum ^{137}Cs concentration of about 860 pCi/g at 8 ft. A zone of lower ^{137}Cs concentrations occurs from about 10 to 18 ft.

^{40}K concentrations are somewhat erratic from 1 to 22 ft. ^{40}K concentrations increase steadily from 1 to about 3.5 ft, reaching a concentration of about 12.5 pCi/g, and then decrease sharply to about 8.4 pCi/g at about 6.5 ft. ^{40}K concentrations increase to about 12 pCi/g from about 7 to 8.5 ft, decrease to less than 10 pCi/g from about 9 to 10.5 ft, and then increase to about 13 pCi/g from about 11.5 to 14 ft. ^{40}K concentrations decrease sharply at about 15 ft, reaching a minimum concentration of about 1.3 pCi/g at 16 ft. ^{40}K concentrations steadily increase from 16.5 to about 21 ft, and are relatively constant below about 23 ft.

The erratic ^{40}K concentrations from 1 to 22 ft are probably the result of irregular presence of grout between the borehole casing and the vadose zone material around the borehole. Almost all the ^{40}K concentrations in this interval are lower than what would be expected for either backfill material or Hanford formation sediments. The low ^{40}K concentrations from about 14.5 to 19.5 ft are probably the result of a thick grouted interval at this depth.

It was not possible to identify many of the 609-keV peaks used to derive the ^{238}U concentrations between 7 and 9.5 ft. This occurred because high gamma-ray activity associated with the nearby ^{137}Cs peak (661 keV) in this interval created an elevated Compton continuum extending to the 609-keV region, causing the MDL to exceed the measured ^{238}U concentration.

A shape factor analysis of the distribution of gamma-ray energies was not performed for this borehole because of the presence of grout around the borehole casing. The presence of grout causes additional attenuation of the gamma rays beyond that which would be caused by vadose zone material, rendering the modeling upon which interpretation of shape factor analysis results is based inapplicable to this borehole.

Historical gross gamma logs from May 1977 through June 1993 were reviewed. No zones of anomalous gamma-ray activity are present in logs from May 6 and May 20, 1977, but a zone of anomalously high gamma-ray activity is present from about 4 to 7 ft in the log from May 13, 1977, and also in later historical logs. It is suspected that contamination was present when the borehole was constructed and that the logs from May 6 and May 20 are mislabeled and actually represent data from another borehole.

The source of the ^{137}Cs contamination in this borehole may be a leak from a pipeline associated with the 241-C-151 Diversion Box. It is also possible that the high ^{137}Cs concentrations at a depth of about 10 ft are actually from contamination in a nearby pipeline. Borehole 30-00-22 is close to several pipelines associated with the 241-C-151 Diversion Box. Because the borehole is located a long distance (i.e., about 247 ft) from tank C-110, it is unlikely that the contamination in the upper 10 ft of the borehole came from a spill or leak associated with tank C-110.

4.9 Borehole 30-00-24

Borehole 30-00-24 is located approximately 118 ft from the southwest side of tank C-110, close to the 241-C-153 Diversion Box. This borehole is not located near tank C-110, but is included in this TSDR for reporting purposes. Borehole 30-00-24 was given the Hanford Site designation 299-E27-122. This borehole was drilled in March 1977 and completed to a depth of 60 ft with 6-in. casing. A driller's log was not available for this borehole; therefore, information from Chamness and Merz (1993) was used to prepare this report. Chamness and Merz (1993) indicate that the borehole was grouted, but do not note perforations. It is therefore assumed that the borehole casing was not perforated. The total logging depth achieved by the SGLS was 58.5 ft.

The only man-made radionuclide detected in this borehole was ^{137}Cs. ^{137}Cs contamination was detected almost continuously from the ground surface to 8 ft and continuously from 20 to 22 ft. Single detections of low ^{137}Cs concentrations occur at depths of 15, 19, 24, 56.5, and 58.5 ft. A well-defined peak occurs at about 20 to 22 ft with a maximum ^{137}Cs concentration of about 0.8 pCi/g at 21 ft.

^{40}K concentrations are somewhat erratic from 1 to 21 ft. ^{40}K concentrations increase steadily from 1 to about 3.5 ft, reaching a concentration of about 14.1 pCi/g, and then decrease sharply to about 8.4 pCi/g at about 6.5 ft. ^{40}K concentrations increase to about 5.4 pCi/g at 8 ft. ^{40}K concentrations gradually increase to about 10 pCi/g at 15 ft, remain at this concentration to 18.5 ft, and then increase to a background concentration of about 15 pCi/g at 21 ft. These variable ^{40}K concentrations from 1 to 21 ft are probably the result of the irregular presence of grout between the borehole casing and the vadose zone material around the borehole. Almost all of the ^{40}K concentrations in this interval are lower than what would be expected for either backfill material or Hanford formation sediments.

A shape factor analysis of the distribution of gamma-ray energies was not performed for this borehole because of the presence of grout around the borehole casing. The presence of grout causes additional attenuation of the gamma rays beyond that which would be caused by vadose zone material, rendering the modeling upon which interpretation of shape factor analysis results is based inapplicable to this borehole.

Historical gross gamma logs from May 1977 through June 1993 were reviewed and a plot of selected logs from May 1977 to November 1980 is included in Appendix A. A zone of anomalous gamma-ray activity is present from about 17 to 21 ft in the earliest logs from May 1977. This zone of anomalously high gamma-ray activity had decreased by about 64 percent by November 1980.

The source of the ^{137}Cs contamination in this borehole may be a surface spill or pipeline leak associated with the 241-C-153 Diversion Box. Because the borehole is located a long distance (i.e., about 118 ft) from tank C-110, it is unlikely that the contamination detected in the borehole originated from a spill or leak associated with tank C-110.

4.10 Borehole 30-00-11

Borehole 30-00-11 is located approximately 232 ft from the southwest side of tank C-110 and was given the Hanford Site designation 299-E27-121. This borehole is not located near tank C-110, but is included in this TSDR for reporting purposes. This borehole was drilled in March 1977 and completed to a depth of 60 ft with 6-in. casing. A driller's log was not available for this borehole; therefore, information from Chamness and Merz (1993) was used to prepare this report. Chamness and Merz (1993) indicate that the borehole was grouted, but do not note any perforations. It is therefore assumed that the borehole casing was not perforated.

The top of the borehole casing is level with the ground surface and is the zero reference point for borehole logging. The top of the borehole casing is against the 241-C-152 Diversion Box. The total logging depth achieved by the SGLS was 58.5 ft.

The only man-made radionuclide detected in this borehole was ^{137}Cs. ^{137}Cs contamination was detected almost continuously from the ground surface to 17.5 ft. The ^{137}Cs concentrations from ground surface to about 11 ft are higher than the concentrations below 11 ft. A region of high ^{137}Cs concentrations occurs from about 8.5 to 11 ft and includes a maximum ^{137}Cs concentration of 2.9 pCi/g at 10.5 ft.

^{40}K concentrations are somewhat variable from 1 to 22 ft. ^{40}K concentrations increase steadily from 1 to about 3.5 ft, reaching a concentration of about 15.8 pCi/g, and then decrease to about 11 to 12 pCi/g from about 6 to 11 ft. ^{40}K concentrations increase steadily to a background of about 17 pCi/g. The variability in ^{40}K concentrations from 1 to 22 ft is probably the result of the irregular presence of grout between the borehole casing and the vadose zone material around the borehole.

It was not possible to identify many of the 609-keV peaks used to derive the ^{238}U concentrations between 9.5 and 11 ft. This occurred because high gamma-ray activity associated with the nearby ^{137}Cs peak (661 keV) in this interval created an elevated Compton continuum extending to the 609-keV region, causing the MDL to exceed the measured ^{238}U concentration.

A shape factor analysis of the distribution of gamma-ray energies was not performed for this borehole because of the presence of grout around the borehole casing. The presence of grout causes additional attenuation of the gamma rays beyond that which would be caused by vadose zone material; therefore, the results of the shape factor analysis cannot be interpreted.

Historical gross gamma logs from May 1977 through June 1993 were reviewed and a plot of selected logs from May 1977 to November 1980 is included in Appendix A. A zone of anomalous gamma-ray activity is present from about 5 to 9 ft in the earliest logs from May 1977, indicating that the contamination was probably in place prior to borehole drilling. The historical records show no evidence of vertical migration.

The source of the ^{137}Cs contamination in this borehole may be a surface spill or pipeline leak associated with the 241-C-152 Diversion Box. It is also possible that the detected contamination is actually within the 241-C-152 Diversion Box rather than in the vadose zone sediments around the borehole. Because the borehole is located far (i.e., about 232 ft) from tank C-110, it is unlikely that the contamination detected in this borehole originated from a spill or leak associated with tank C-110.

5.0 Discussion of Results

A correlation plot of the man-made radionuclide concentration profiles for the boreholes surrounding tank C-110 is presented in Figure 3. A plot of the profiles for the three boreholes more than 100 ft from the side of tank C-110 (i.e., boreholes 30-00-24, 30-00-22, and 30-00-11) is presented on a separate page. The plot for these three boreholes shows ^{137}Cs contamination down to about 20 ft in all three boreholes.

^{137}Cs contamination was detected in the upper portions of all the boreholes surrounding tank C-110. This near-surface contamination is probably the result of surface spills that migrated into the backfill material around the tank. However, because the upper 11 ft of borehole 30-00-09 is located above ground level or in a steep hillside, the ^{137}Cs contamination detected from 1 to 3 ft may be caused by surface contamination detected through the casing and soil, rather than by contamination in the vadose zone around the borehole. In addition, because double casing is probably present in borehole 30-00-09 below about 4 ft, it is not possible to determine if contamination is present in the vadose zone around the borehole.

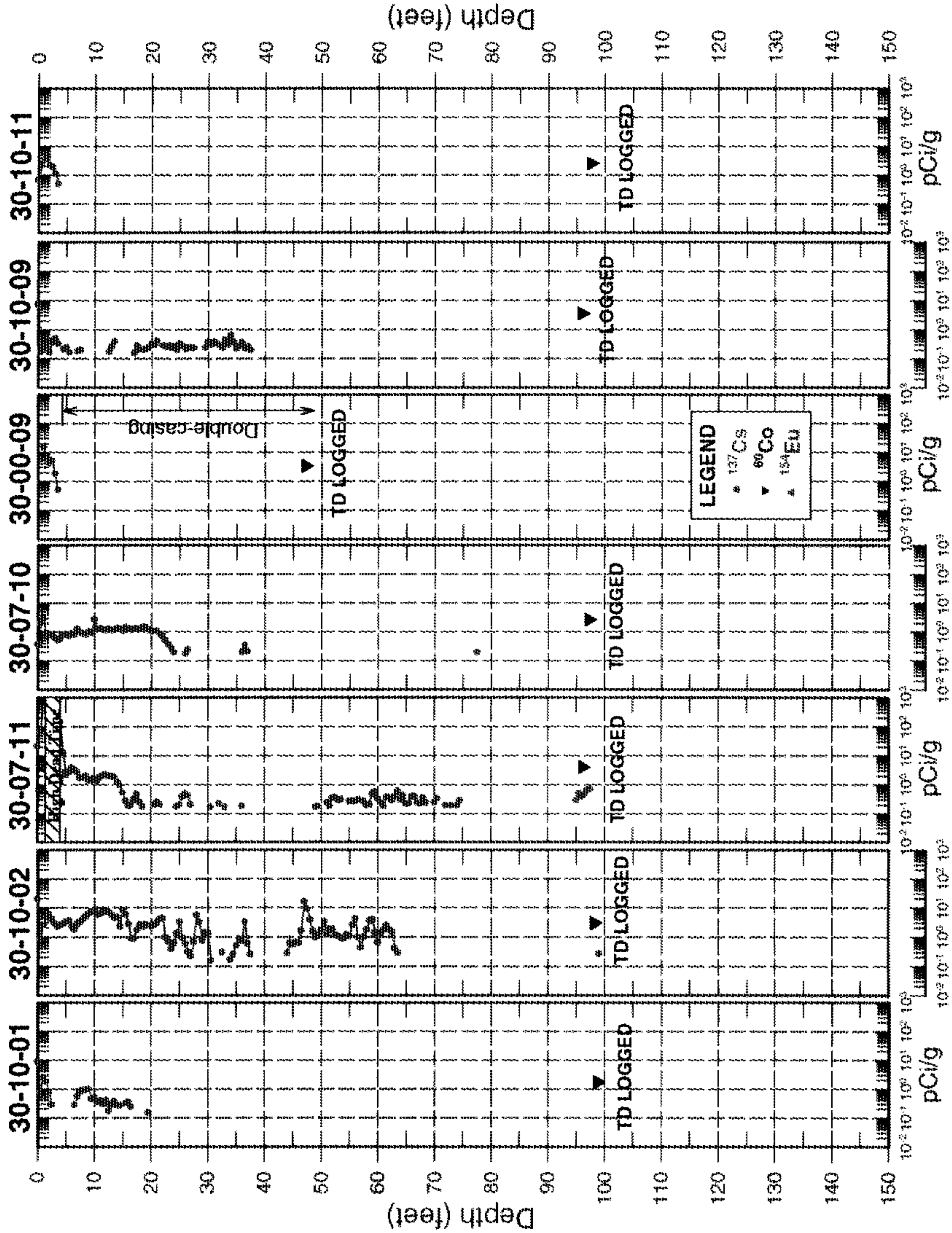

Figure 3. Correlation Plot of ^{137}Cs, ^{60}Co, and ^{154}Eu Concentrations in Boreholes Surrounding Tank C-110

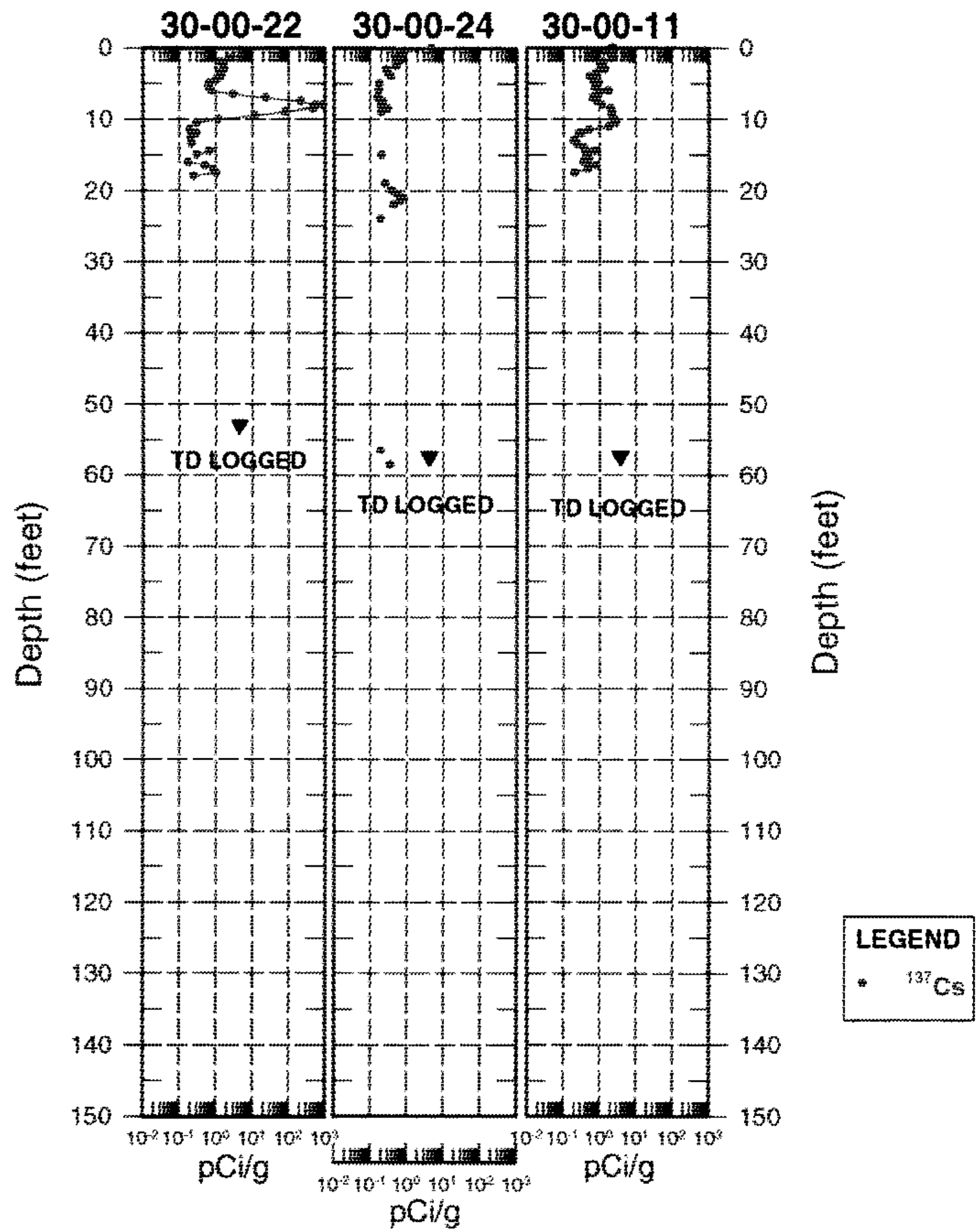

Figure 3 (continued). Correlation Plot of ^{137}Cs, ^{60}Co, and ^{154}Eu Concentrations in Boreholes Surrounding Tank C-110

The ^{137}Cs contamination detected in borehole 30-10-02 from 44 to 63.5 ft and borehole 30-07-11 from 49 to 74.5 ft may be the result of a tank or pipeline leak that has migrated into the Hanford formation sediments beneath the tank. The contamination appears to be correlatable and continuous between the two boreholes. Shape factor analysis of the contamination detected in borehole 30-10-02 indicates that the contamination is in the formation around the borehole, rather than in the immediate vicinity of the borehole casing. The ^{137}Cs concentrations detected from 49 to 74.5 ft in borehole 30-07-11 are too low to perform a shape factor analysis.

The ^{137}Cs, ^{60}Co, and ^{154}Eu contamination detected in borehole 30-07-11 from 1 to 4 ft is probably from material remaining within the transfer line. Soil sampling was conducted around the tank. In addition, an investigation conducted in 1992 indicated that the contamination detected in the borehole at this depth was actually contained in an improperly designed salt-well transfer line (Winkler 1992).

A review of historical gross gamma-ray logs for borehole 30-10-09 indicates that a leak may have occurred in tank C-110 before 1975. The anomalous gross gamma-ray activity from about 43 to 60 ft appears to have decreased to background levels by 1980. On the basis of the apparent decay rate observed in the historical logs from January 1975 through January 1978, the contaminant responsible for this activity may have been ^{106}Ru, which has now decayed away.

Data collected from boreholes 30-00-24, 30-00-22, and 30-00-11 indicate ^{137}Cs contamination in the upper section of all these boreholes. Because these boreholes are located far from tank C-110, the contamination in these boreholes is probably not associated with leaks or spills from tank C-110. All three boreholes are located near diversion boxes and their associated piping. The contamination detected around these boreholes is probably associated with the diversion boxes, rather than tank C-110.

6.0 Conclusions

The characterization of the gamma-ray-emitting contamination in the vadose zone surrounding tank C-110 was completed using the SGLS. Data obtained with the SGLS and geologic and historical information indicate that the source of the ^{137}Cs contamination around this tank is a combination of surface spills and pipeline and tank leaks. On the basis of a review of historical gross gamma-ray logs for borehole 30-10-09, a tank leak may have occurred before 1975. The source of the tank leak is probably closest to borehole 30-10-09, on the west side of tank C-110.

7.0 Recommendations

Approximately 29,000 gal of drainable supernatant and interstitial liquid remains in tank C-110 (Hanlon 1997). It is recommended that logging of the boreholes surrounding this tank be continued to detect potential future leakage from the tank and associated tank facilities and to monitor the potential spread of contaminant plumes detected during this study. Changes in the contamination profiles would show contaminant migration.

It is further recommended that borehole 30-00-09 be replaced with a new single-cased non-perforated borehole. The double casing makes the borehole practically unusable for vadose zone monitoring. A new monitoring borehole should be constructed in this general area to monitor possible contaminant migration.

8.0 References

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Appendix A
Spectral Gamma-Ray Logs for Boreholes in the Vicinity of Tank C-110

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Spectral Gamma-Ray Borehole Log Data Report

Log Event A

Borehole 30-10-01

Borehole Information

Farm : C	Tank : C-110	Site Number : 299-E27-101
N-Coord : 42,979	W-Coord : 48,528	TOC Elevation : 648.00
Water Level, ft : None	Date Drilled : 9/30/74	

Casing Record

Type : Steel-welded	Thickness : 0.280	ID, in. : 6
Top Depth, ft. : 0	Bottom Depth, ft. : 100	

Borehole Notes:
This borehole was drilled in September 1974 and completed to a depth of 100 ft with 6-in.-diameter casing. A driller's log for this borehole was not available; therefore, information from Chamness and Merz (1993) was used to prepare this report. No information indicated that the borehole was grouted or that the casing was perforated; therefore, it is assumed that the borehole was not grouted or perforated. The casing thickness is assumed to be 0.280 in., on the basis of the published thickness for schedule-40, 6-in. casing.

The top of the casing is the zero reference for the log. The casing lip is approximately even with the ground surface.

Equipment Information

Logging System : 2	Detector Type : HPGe	Detector Efficiency : 35.0 %
Calibration Date : 10/96	Calibration Reference : GJO-HAN-13	Logging Procedure : P-GJPO-1783

Log Run Information

Log Run Number : 1	Log Run Date : 3/4/97	Logging Engineer: Bob Spatz	
Start Depth, ft.: 100.0	Counting Time, sec.: 100	L/R : L	Shield : N
Finish Depth, ft. : 53.5	MSA Interval, ft. : 0.5	Log Speed, ft/min.: n/a	

Log Run Number : 2	Log Run Date : 3/5/97	Logging Engineer: Bob Spatz	
Start Depth, ft.: 0.0	Counting Time, sec.: 100	L/R : L	Shield : N
Finish Depth, ft. : 13.0	MSA Interval, ft. : 0.5	Log Speed, ft/min.: n/a	

Log Run Number : 3	Log Run Date : 3/5/97	Logging Engineer: Bob Spatz	
Start Depth, ft.: 54.5	Counting Time, sec.: 100	L/R : L	Shield : N
Finish Depth, ft. : 12.0	MSA Interval, ft. : 0.5	Log Speed, ft/min.: n/a	

Log Event A

Borehole 30-10-01

Analysis Information

Analyst : H.D. Mac Lean

Data Processing Reference : MAC-VZCP 1.7.9 Analysis Date : 9/5/97

Analysis Notes :

The SGLS log of this borehole was completed in three logging runs. A centralizer was used during all runs.

The pre- and post-survey field verification spectra for all logging runs met the acceptance criteria established for peak shape and system efficiency. The energy and peak-shape calibration that best matched the logging run data were used to establish the channel-to-energy parameters used in processing the spectra acquired during the logging runs. There was negligible gain drift during the logging runs, and it was not necessary to adjust the established channel-to-energy parameters to maintain proper peak identification.

Casing correction factors for a 0.280-in.-thick casing were applied during the analysis.

Cs-137 was the only man-made radionuclide detected in this borehole. Cs-137 contamination was detected continuously from the ground surface to 2.5 ft, continuously from depths of 6.5 to 17 ft, and at a depth of 19.5 ft. The measured concentrations of the subsurface Cs-137 occurrences ranged from 0.15 pCi/g (just above the MDL) to about 2.5 pCi/g at a depth of 1 ft. A zone of slightly elevated contamination (about 1 pCi/g) was detected at a depth of 9 ft. The highest measured Cs-137 concentration (8.9 pCi/g) was detected at the ground surface.

The logs of the naturally occurring radionuclides show that the K-40 concentrations increase from a background of about 13 pCi/g above 38 ft to about 16.5 pCi/g at 38 ft. Below the 50-ft depth, the K-40 concentrations remain slightly elevated with a background of about 16 pCi/g. Th-232 concentrations increase in the interval from 76 to 79 ft.

An analysis of the shape factors associated with applicable segments of the spectra was performed. The shape factors provide insights into the distribution of the Cs-137 contamination and into the nature of zones of elevated total count gamma-ray activity not attributable to gamma-emitting radionuclides.

Details concerning the interpretation of data for this borehole are presented in the Tank Summary Data Reports for tanks C-110 and C-111.

Log Plot Notes:

Separate log plots show the man-made and the naturally occurring radionuclides. The natural radionuclides can be used for lithology interpretations. The headings of the plots identify the specific gamma rays used to calculate the concentrations.

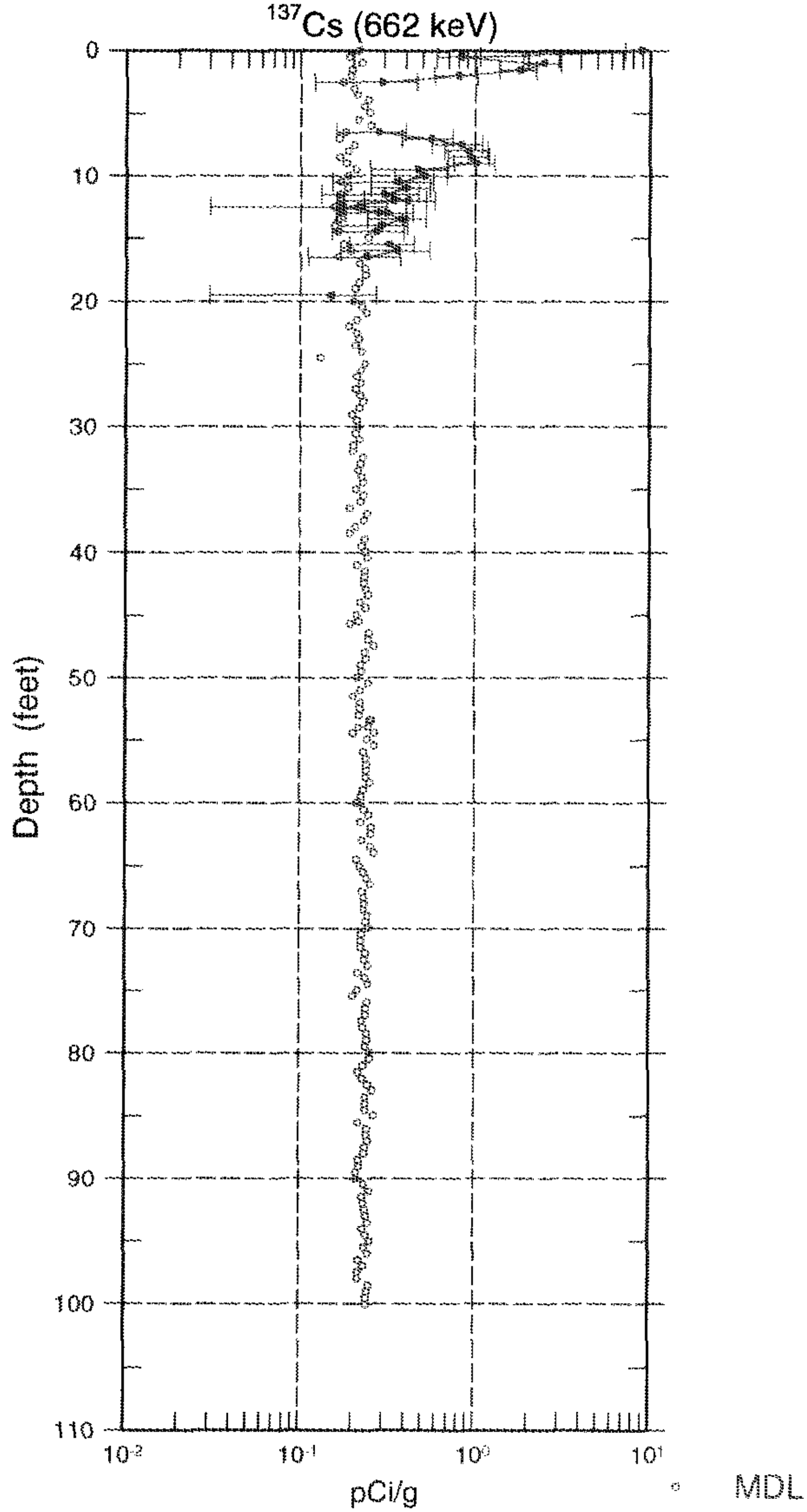
Uncertainty bars on the plots show the statistical uncertainties for the measurements as 95-percent confidence intervals. Open circles on the plots give the MDL. The MDL of a radionuclide represents the lowest concentration at which positive identification of a gamma-ray peak is statistically defensible.

A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with the SGLS data.

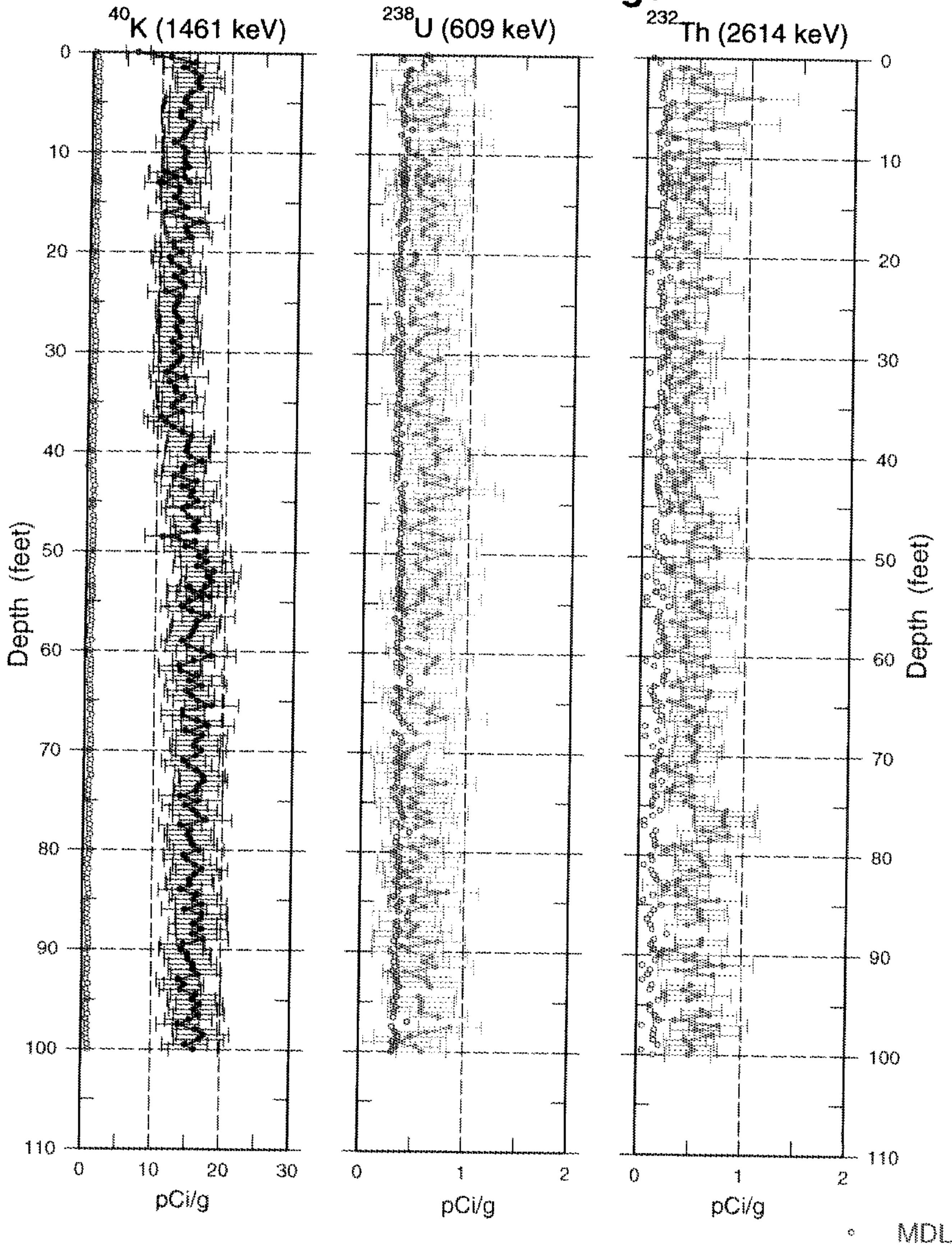
Plots of the spectrum shape factors are included. The plots are used as an interpretive tool to help assess the radial distribution of man-made contaminants around the borehole.

30-10-01

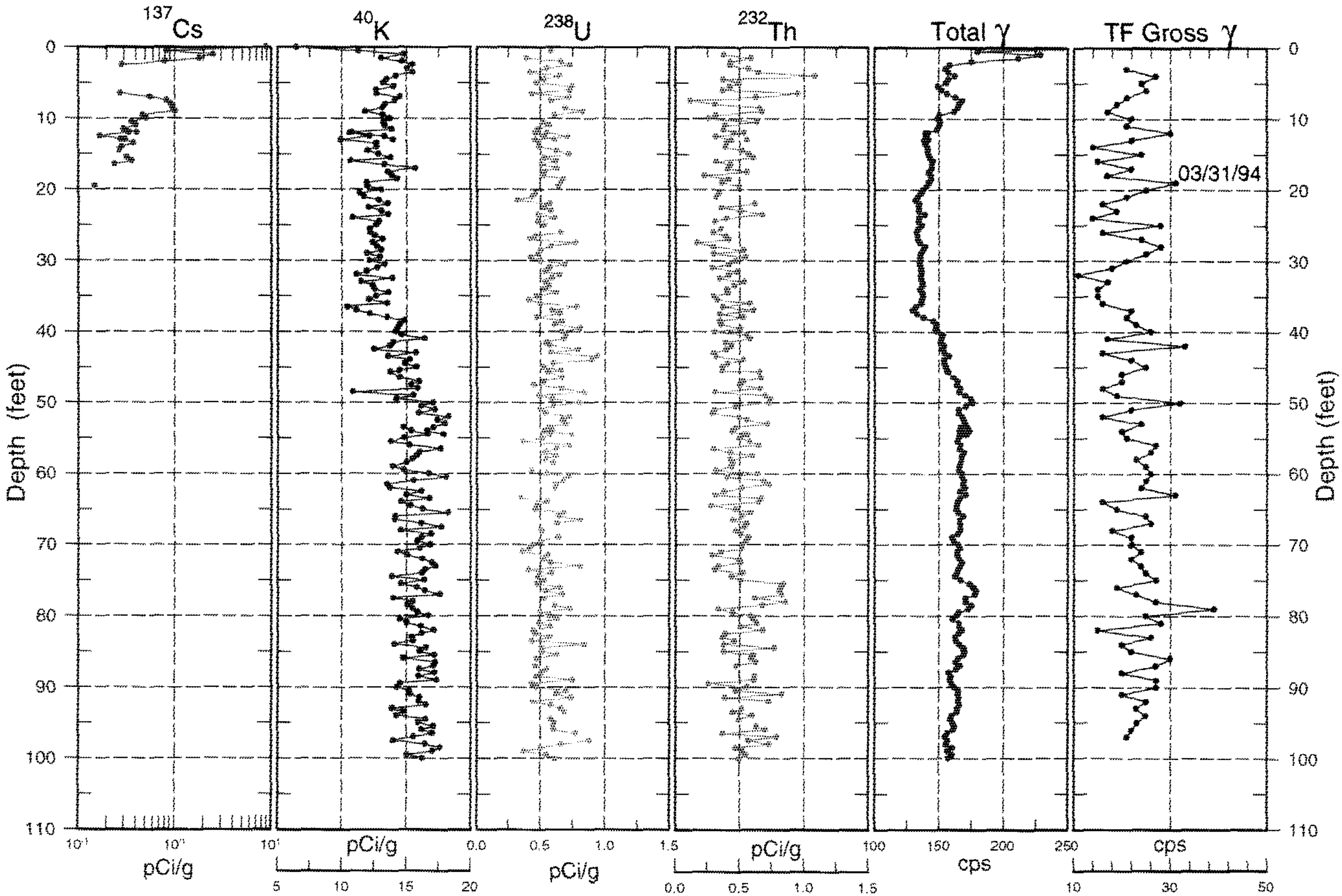
Man-Made Radionuclide Concentrations



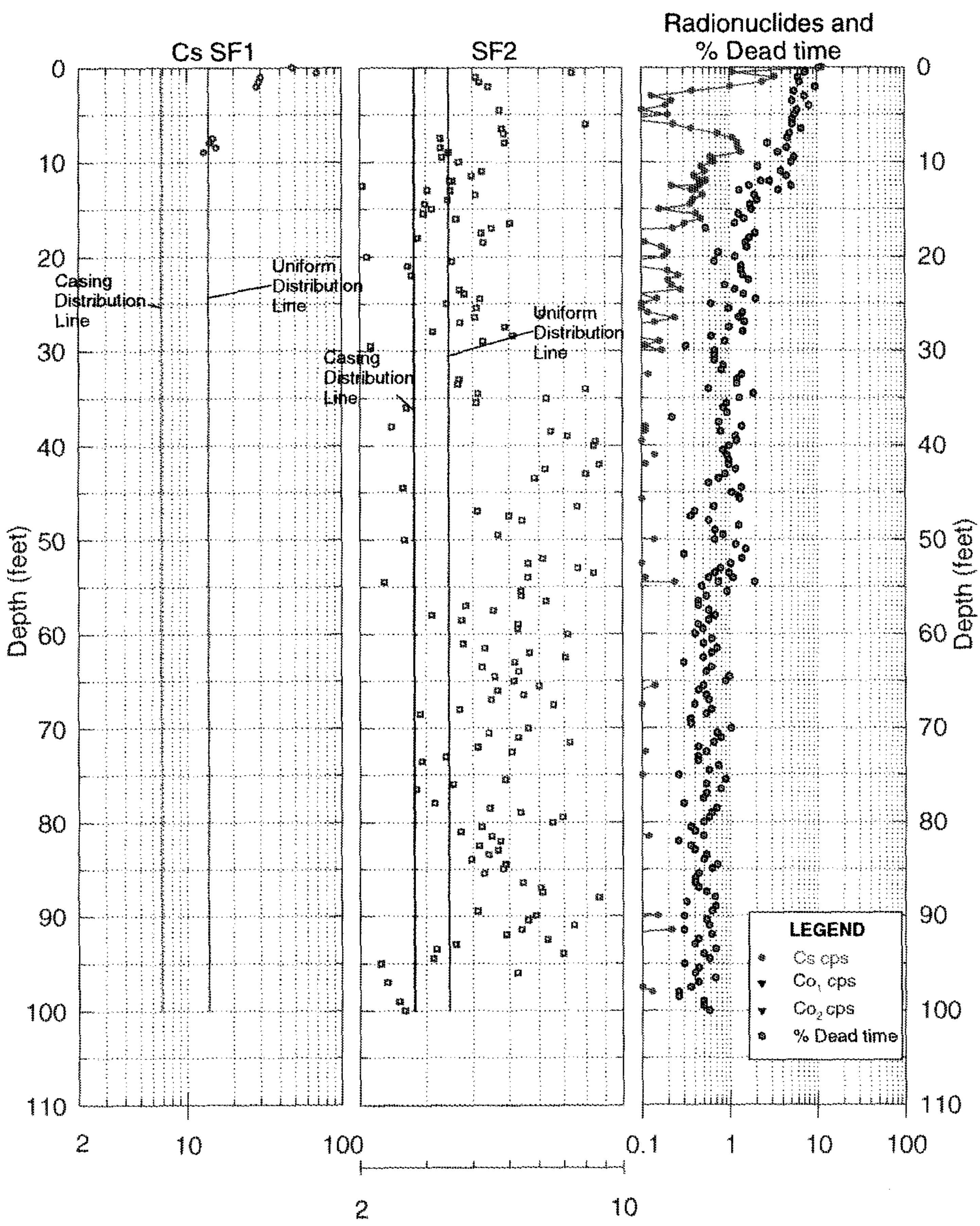
30-10-01
Natural Gamma Logs



30-10-01 Combination Plot



30-10-01
Shape Factor Analysis Logs



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Spectral Gamma-Ray Borehole Log Data Report

Log Event A

Borehole 30-10-02

Borehole Information

Farm :	C	Tank :	C-110	Site Number :	299-E27-102
N-Coord :	42,945	W-Coord :	48,494	TOC Elevation :	648.00
Water Level, ft :	None	Date Drilled :	9/30/74		

Casing Record

Type :	Steel-welded	Thickness :	0.280	ID, in. :	6
Top Depth, ft. :	0	Bottom Depth, ft. :	100		

Borehole Notes:

This borehole was drilled in September 1974 and completed to a depth of 100 ft with 6-in. diameter casing. A driller's log for this borehole was not available; therefore, information from Chamness and Merz (1993) was used to prepare this report. No information indicated that the borehole was grouted or that the casing was perforated; therefore, it is assumed that the borehole was not grouted or perforated. The casing thickness is assumed to be 0.280 in., on the basis of the published thickness for schedule-40, 6-in. casing.

The top of the casing is the zero reference for the log. The casing lip is approximately even with the ground surface.

Equipment Information

Logging System :	2	Detector Type :	HPGe	Detector Efficiency :	35.0 %
Calibration Date :	10/96	Calibration Reference :	GJO-HAN-13	Logging Procedure :	P-GJPO-1783

Log Run Information

Log Run Number :	1	Log Run Date :	2/27/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	99.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	38.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Log Run Number :	2	Log Run Date :	2/28/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	39.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	0.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Log Run Number :	3	Log Run Date :	2/28/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	40.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	20.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Analysis Information

Analyst : H.D. Mac Lean

Data Processing Reference : MAC-VZCP 1.7.9 Analysis Date : 9/5/97

Analysis Notes :

The SGLS log of this borehole was completed in three logging runs. Two logging runs were required to complete the log of the borehole. A third logging run repeated a segment of the borehole as an additional quality assurance check and to observe the repeatability of the radionuclide concentration measurements. A centralizer was used during all runs.

The pre- and post-survey field verification spectra for all logging runs met the acceptance criteria established for peak shape and system efficiency. The energy and peak-shape calibration that best matched the logging run data were used to establish the channel-to-energy parameters used in processing the spectra acquired during the logging runs. There was negligible gain drift during the logging runs, and it was not necessary to adjust the established channel-to-energy parameters to maintain proper peak identification.

Casing correction factors for a 0.280-in.-thick casing were applied during the analysis.

Cs-137 was the only man-made radionuclide detected in this borehole. Cs-137 contamination was detected continuously from the ground surface to a depth of 30.5 ft, at 32.5 ft, continuously from 34 to 37.5 ft, and from 44 to 63.5 ft. The measured Cs-137 concentrations ranged from about 0.2 pCi/g (just above the MDL) to about 10 pCi/g. The highest measured subsurface concentration was about 16.5 pCi/g at a depth of 47 ft. Zones of generally higher contamination levels were detected at depths of approximately 2, 12.5, 25, 28, 36.5, and 47 ft. The measured Cs-137 concentration at the ground surface was 20.2 pCi/g.

A zone of slightly elevated K-40 concentrations occurs between depths of 38 and 40 ft. The logs of the naturally occurring radionuclides show an increase in K-40 concentrations from a background of about 13 pCi/g above a depth of 40 ft to about 16 pCi/g from 49 to 60 ft and to about 17 pCi/g below the 60-ft depth. The U-238 concentrations also increase below a depth of about 60 ft.

An analysis of the shape factors associated with applicable segments of the spectra was performed. The shape factors provide insights into the distribution of the Cs-137 contamination and into the nature of zones of elevated total count gamma-ray activity not attributable to gamma-emitting radionuclides.

Details concerning the interpretation of data for this borehole are presented in the Tank Summary Data Reports for tanks C-110 and C-111.

Log Plot Notes:

Separate log plots show the man-made and the naturally occurring radionuclides. The natural radionuclides can be used for lithology interpretations. The headings of the plots identify the specific gamma rays used to calculate the concentrations.

Uncertainty bars on the plots show the statistical uncertainties for the measurements as 95-percent confidence intervals. Open circles on the plots give the MDL. The MDL of a radionuclide represents the lowest concentration at which positive identification of a gamma-ray peak is statistically defensible.

A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with the SGLS data.

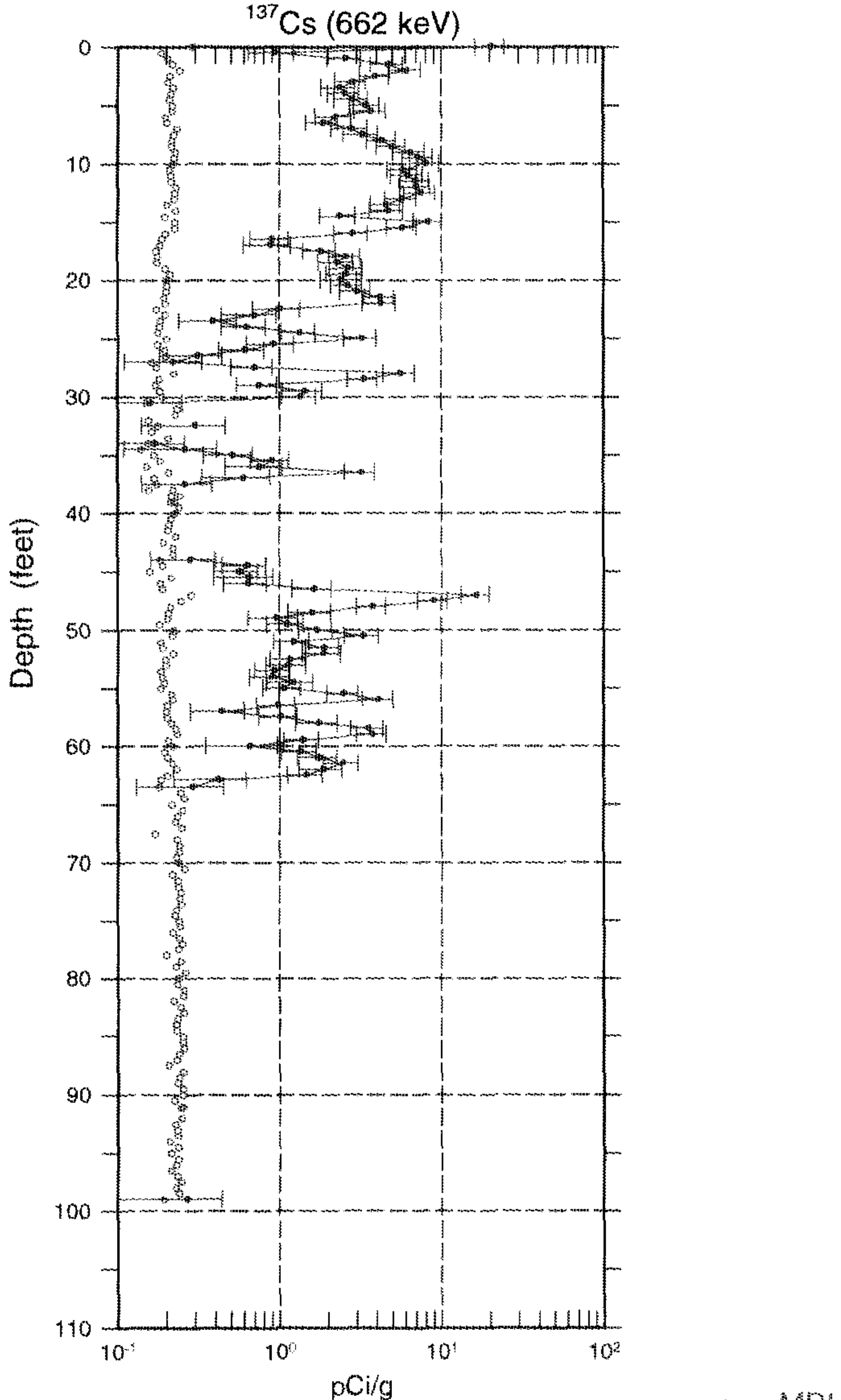
A separate plot is included for the repeated segment of the log. The plot shows the concentrations of the Cs-137 and the naturally occurring radionuclides measured by the original and repeated logging runs. The uncertainty of each measurement is indicated on the plot. The concentrations measured by the original and repeated logging runs are generally within the two sigma (95 percent) confidence level of the measurements.

A plot of representative historical gross gamma-ray logs from 1975 to 1983 is included.

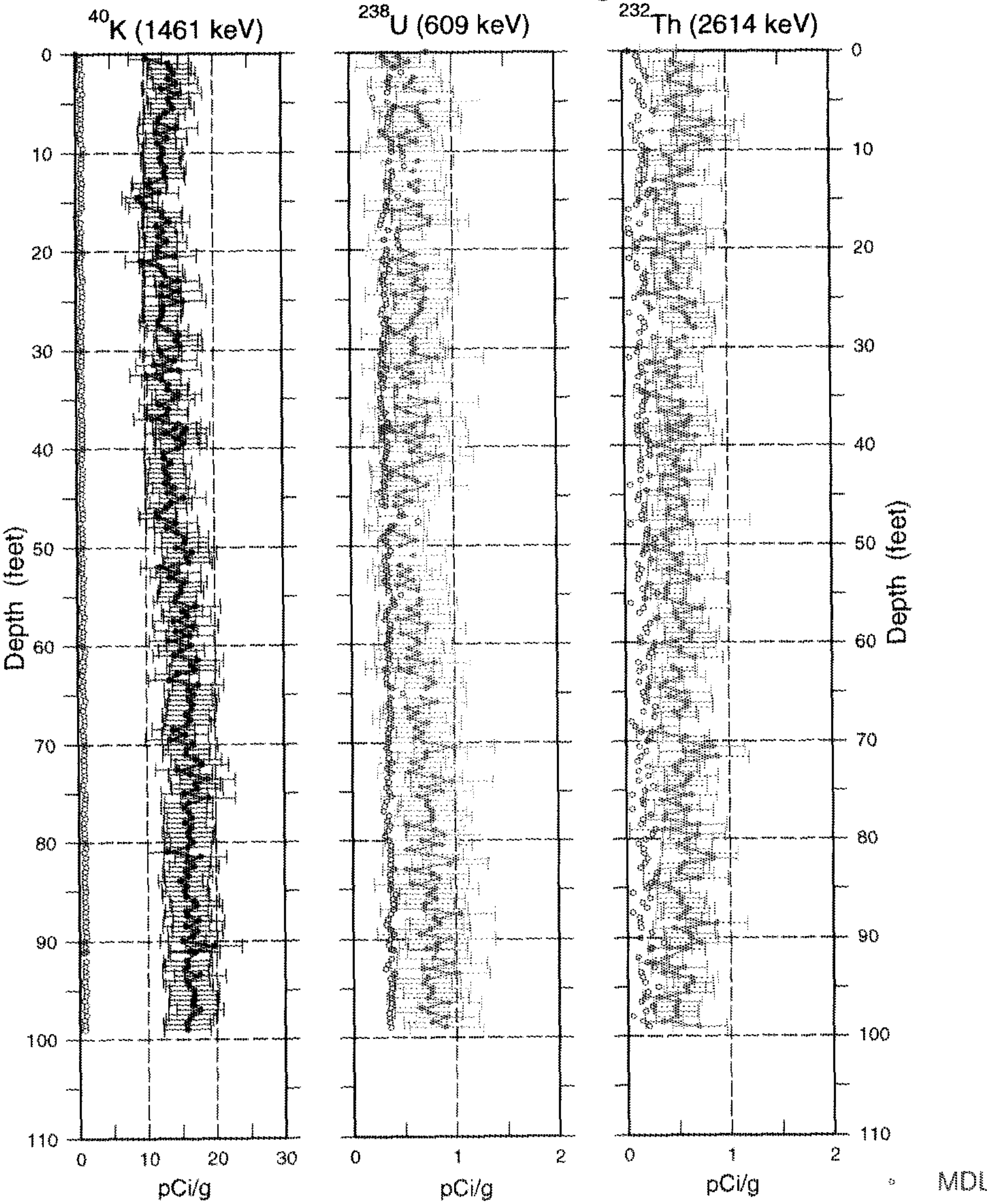
Plots of the spectrum shape factors are included. The plots are used as an interpretive tool to help determine the radial distribution of man-made contaminants around the borehole.

30-10-02

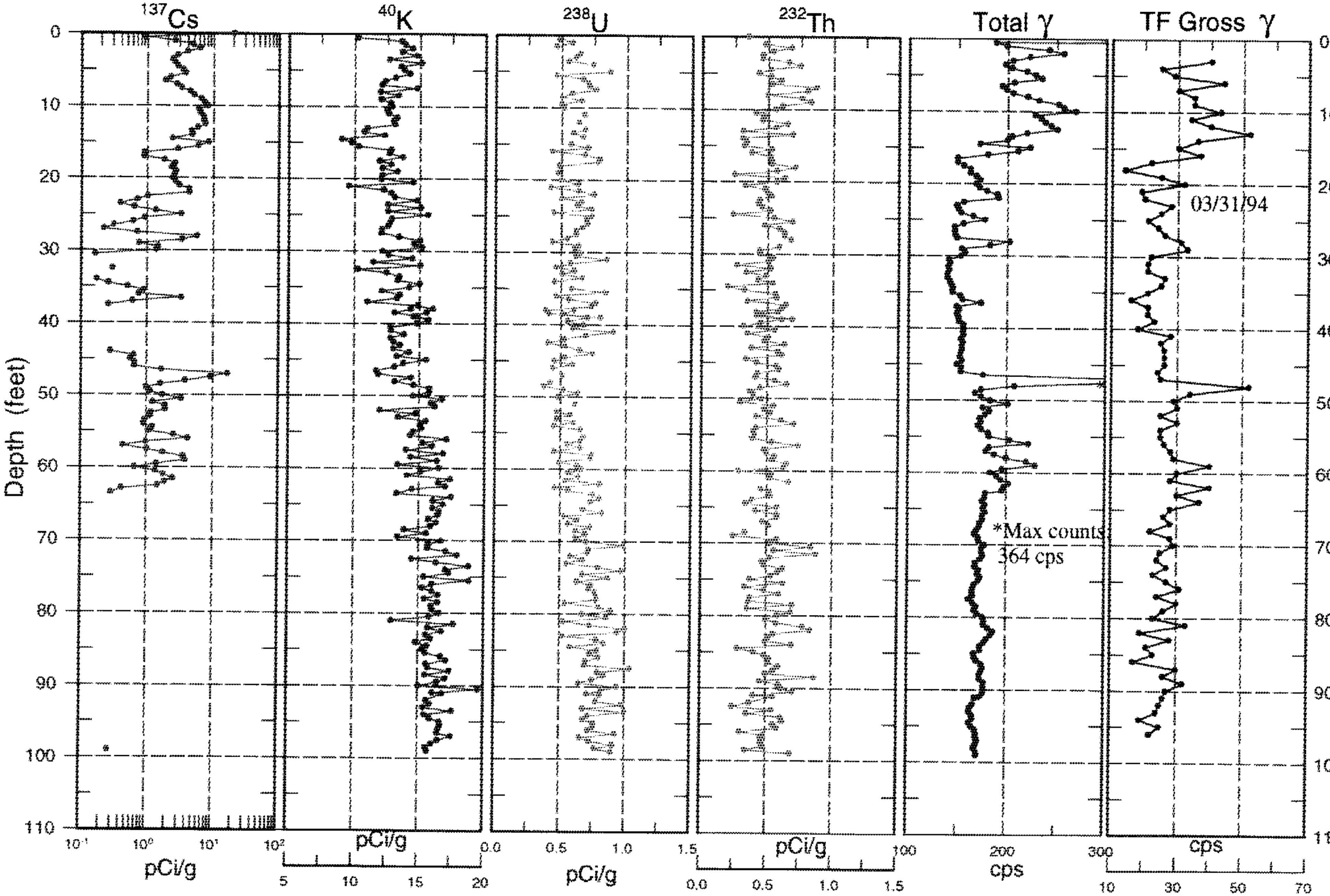
Man-Made Radionuclide Concentrations



30-10-02
Natural Gamma Logs

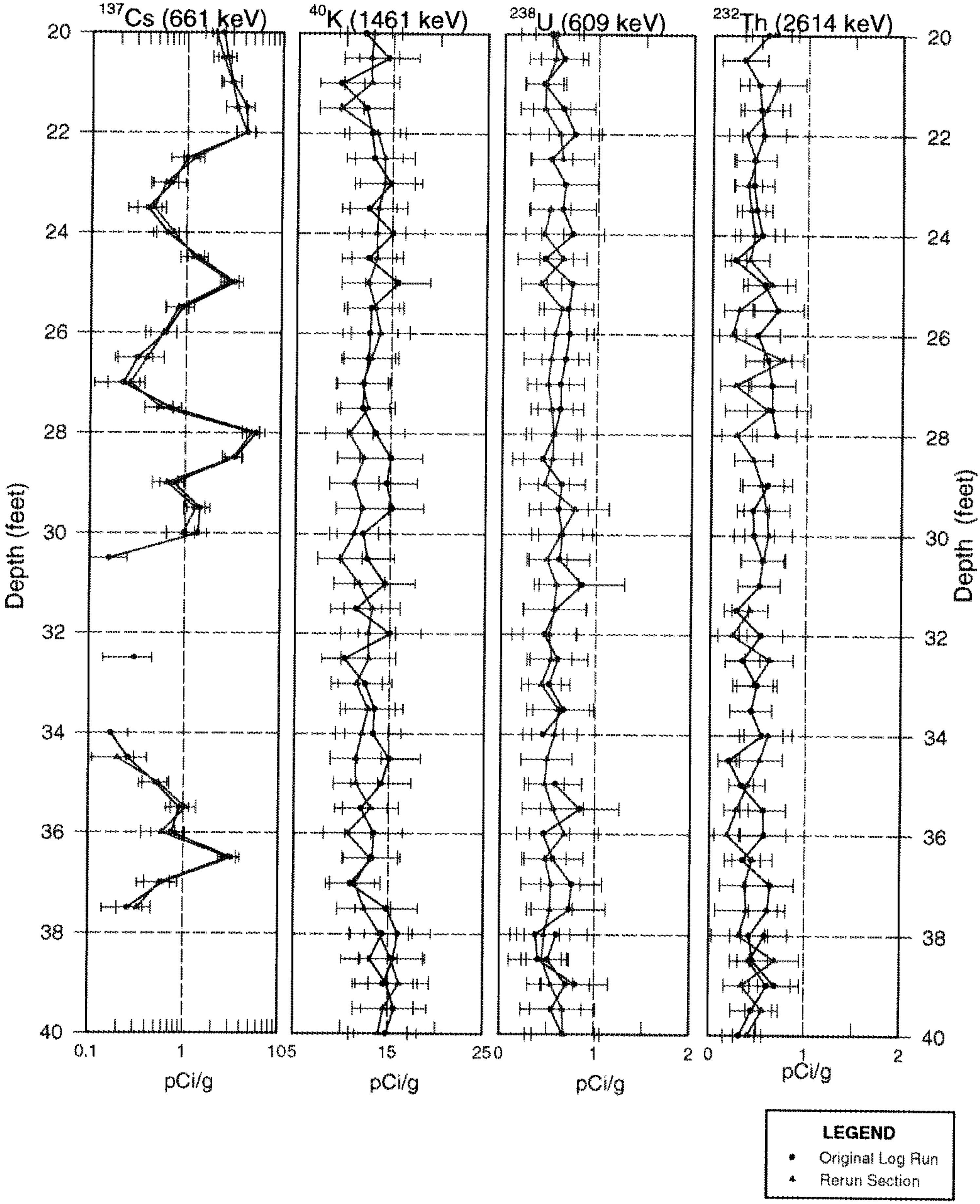


30-10-02 Combination Plot

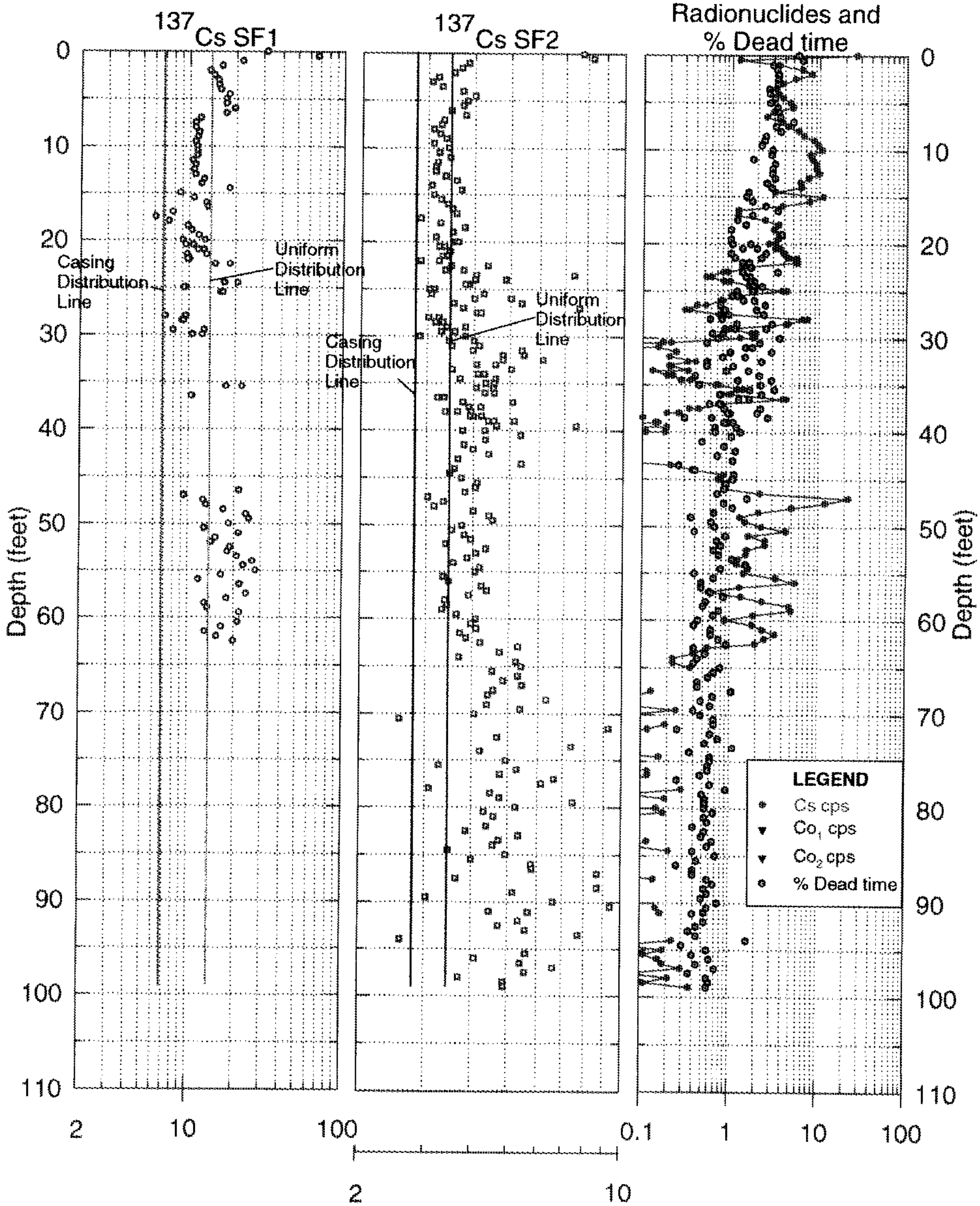


30-10-02

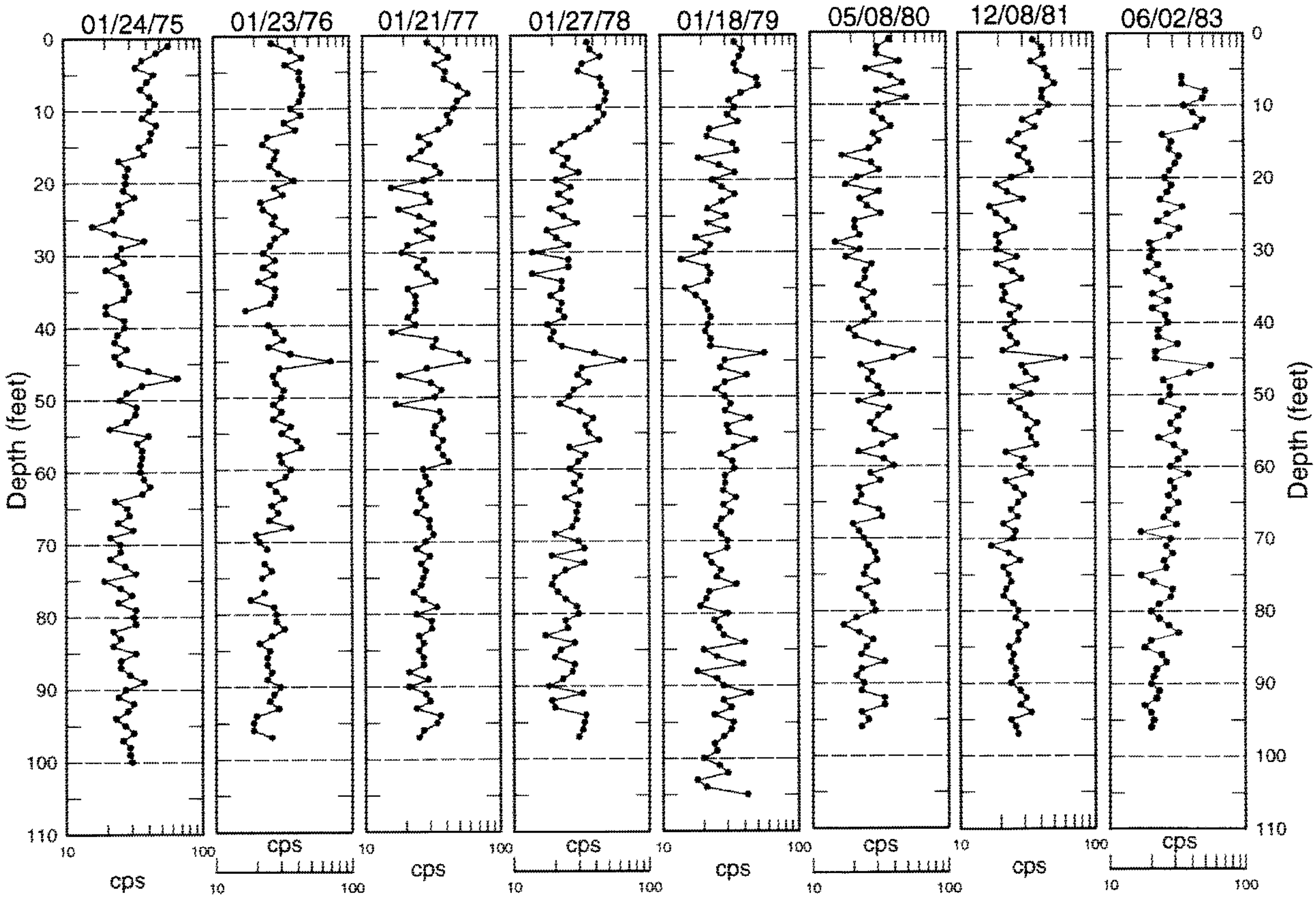
Rerun Section of Man-Made and Natural Gamma Logs



30-10-02
Shape Factor Analysis Logs



Historical Gross Gamma Logs for Borehole 30-10-02



Spectral Gamma-Ray Borehole Log Data Report

Log Event A

Borehole 30-07-11

Borehole Information

Farm :	C	Tank :	C-107	Site Number :	299-E27-93
N-Coord :	42,904	W-Coord :	48,489	TOC Elevation :	646.59
Water Level, ft :	None	Date Drilled :	7/31/74		

Casing Record

Type :	Steel-welded	Thickness :	0.280	ID, in. :	6
Top Depth, ft. :	0	Bottom Depth, ft. :	97		

Borehole Notes:
Borehole 30-07-11 was drilled in July 1974 to a depth of 100 ft with 6-in. casing. The casing thickness is presumed to be 0.280 in., on the basis of the published thickness for schedule-40, 6-in. steel tubing. No information concerning grouting or perforations was available; therefore, it is assumed that the borehole was not grouted or perforated. The top of the casing, which is the zero reference for the SGLS, is approximately 6 in. above the ground surface.

Equipment Information

Logging System :	2	Detector Type :	HPGe	Detector Efficiency :	35.0 %
Calibration Date :	10/96	Calibration Reference :	GJO-HAN-13	Logging Procedure :	P-GJPO-1783

Log Run Information

Log Run Number :	1	Log Run Date :	3/10/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	0.0	Counting Time, sec.:	100	L/R :	R	Shield :	N
Finish Depth, ft. :	5.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Log Run Number :	2	Log Run Date :	3/11/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	97.5	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	19.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Log Run Number :	3	Log Run Date :	3/12/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	20.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	4.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Borehole 30-07-11

Log Event A

Analysis Information

Analyst : D.L. Parker

Data Processing Reference : MAC-VZCP 1.7.9 Analysis Date : 8/20/97

Analysis Notes :

This borehole was logged by the SGLS in three log runs. The pre- and post-survey field verification spectra met the acceptance criteria established for the peak shape and detector efficiency, confirming that the SGLS was operating within specifications. The energy calibration and peak-shape calibration from these spectra were used to establish the peak resolution and the channel-to-energy parameters used in processing the spectra acquired during the logging operation.

The upper 5 ft of the borehole was logged in real time because of high dead time during the first log run. Accurate radionuclide concentrations could not be determined for the interval from 1.5 to 3.5 ft because the dead time exceeded 81 percent.

Casing correction factors for a 0.280-in.-thick steel casing were applied during analysis.

The man-made radionuclides detected in this borehole were Cs-137, Co-60, and Eu-154. The presence of Cs-137 was measured almost continuously from the ground surface to 19 ft, intermittently from 20.5 to 36 ft, intermittently from 49 to 74.5 ft, and near the bottom of the logged interval (97.5 ft). Co-60 contamination was detected at 4 ft. Eu-154 concentrations were detected at 0.5, 1, and 4 ft.

The U-238 and Th-232 concentration data are absent along several short intervals throughout the length of the borehole.

The K-40 concentrations are relatively elevated from 38 to 40 ft. KUT concentrations are elevated below about 49 ft. Th-232 concentrations are highly variable over the depth of the borehole.

Shape factor data analysis was performed using the SGLS data from this borehole.

Additional information and interpretations of log data are included in the main body of the Tank Summary Data Reports for tanks C-107 and C-110.

Log Plot Notes:

Separate log plots show the man-made and the naturally occurring radionuclides. The natural radionuclides can be used for lithology interpretations. The headings of the plots identify the specific gamma rays used to calculate the concentrations.

Uncertainty bars on the plots show the statistical uncertainties for the measurements as 95-percent confidence intervals. Open circles on the plots give the MDL. The MDL of a radionuclide represents the lowest concentration at which positive identification of a gamma-ray peak is statistically defensible.

A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with the SGLS data.

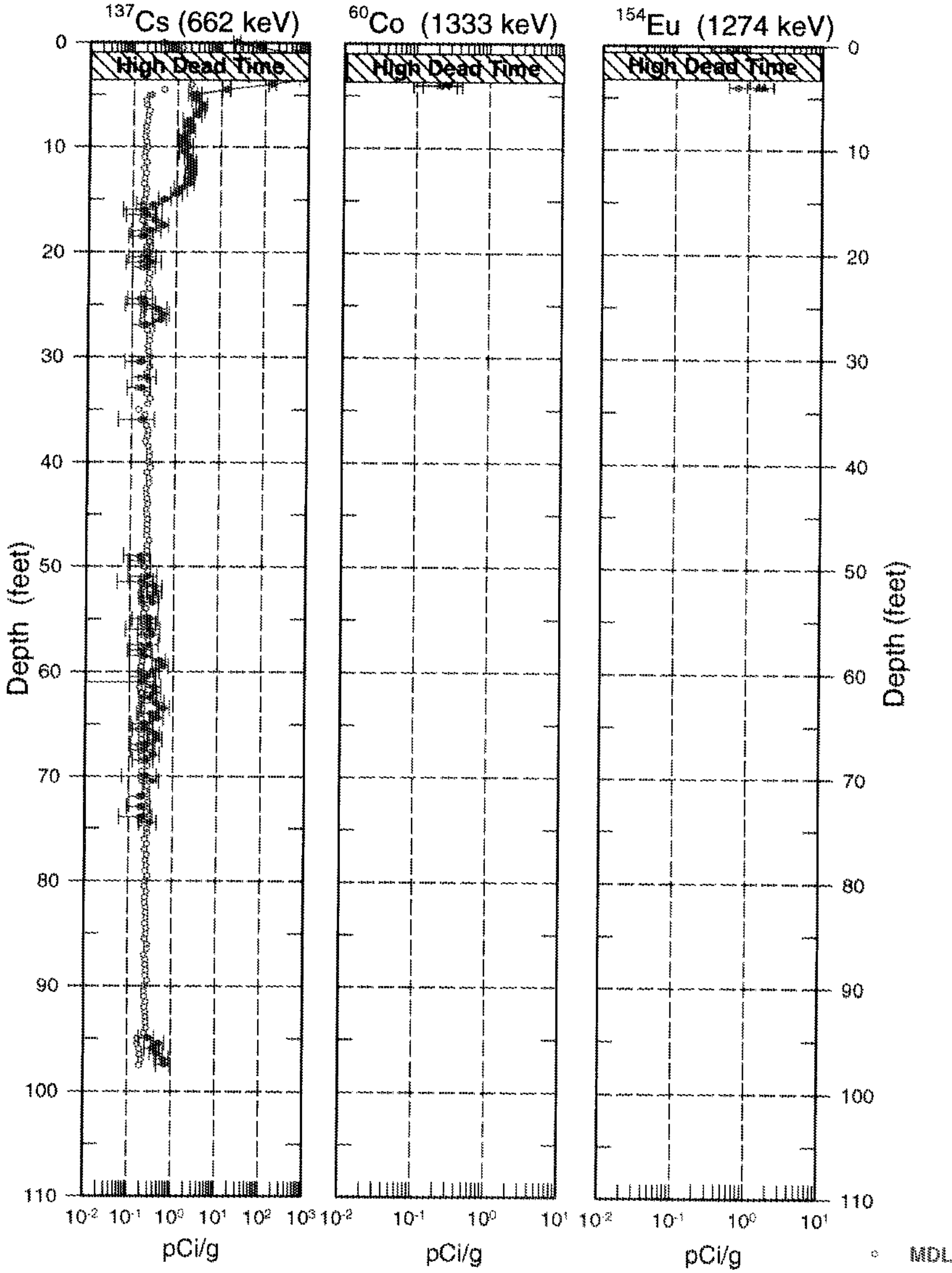
Log Event A

Borehole 30-07-11

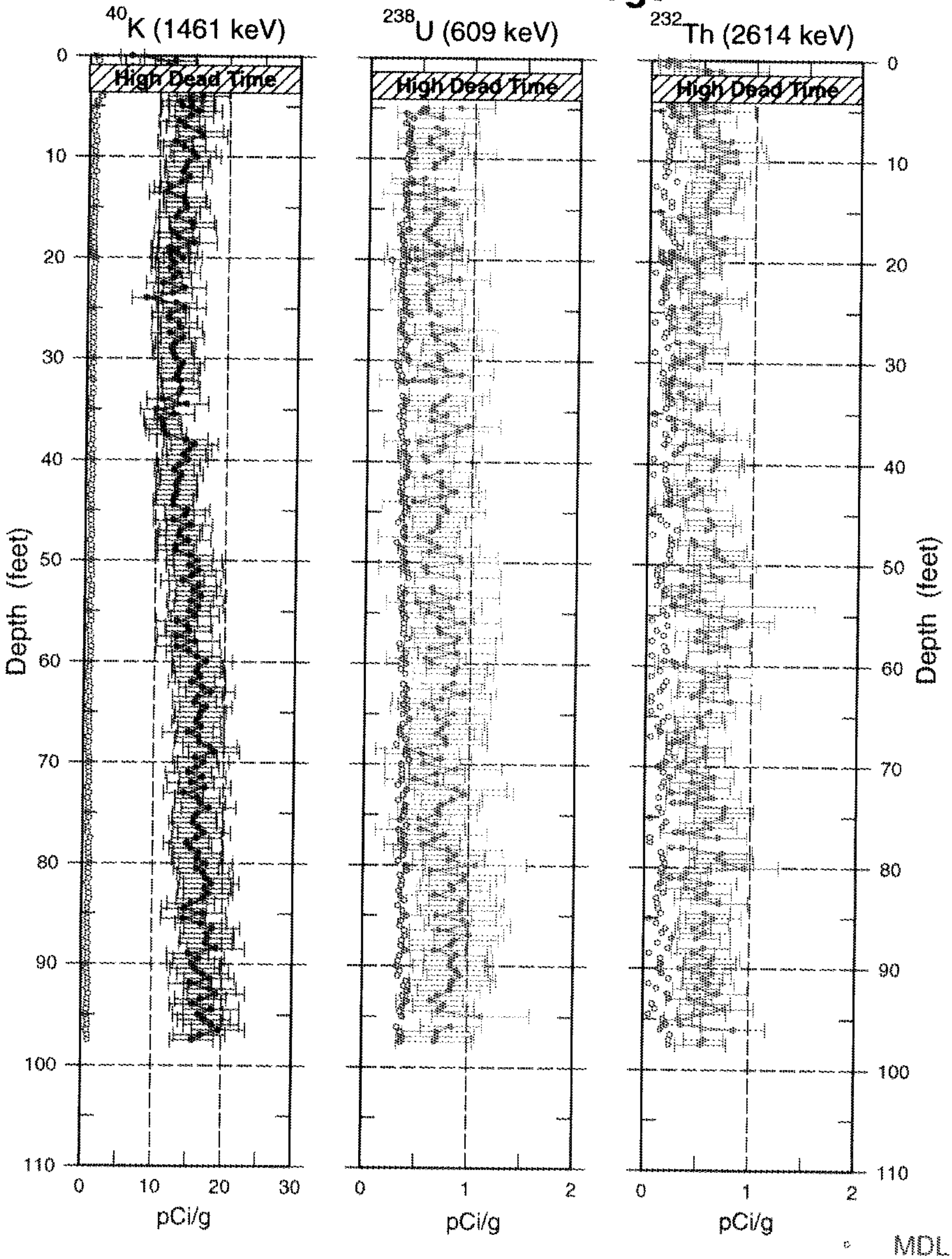
A plot showing the results of the shape factor analysis is included with the set of plots for this borehole.

30-07-11

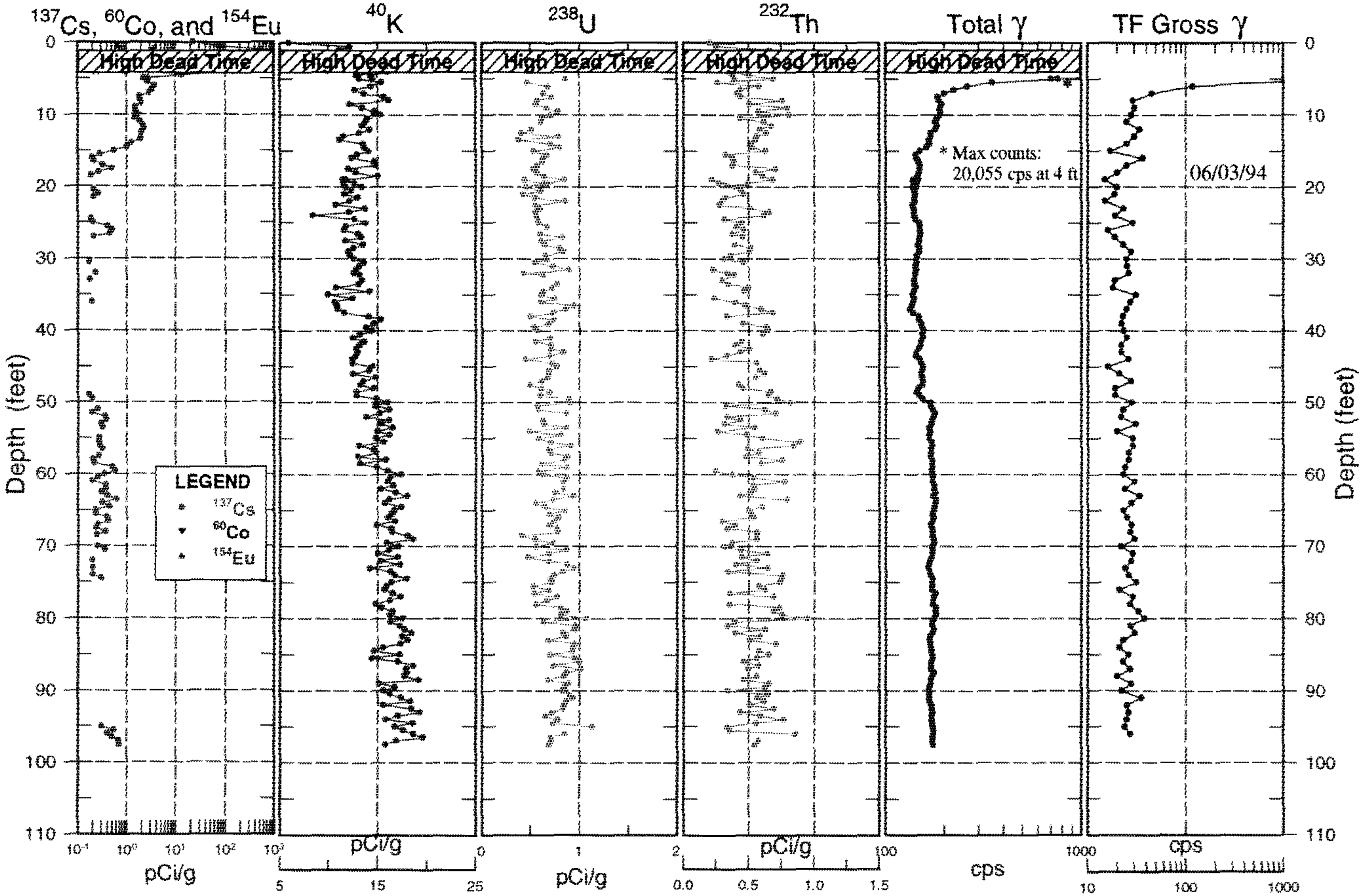
Man-Made Radionuclide Concentrations



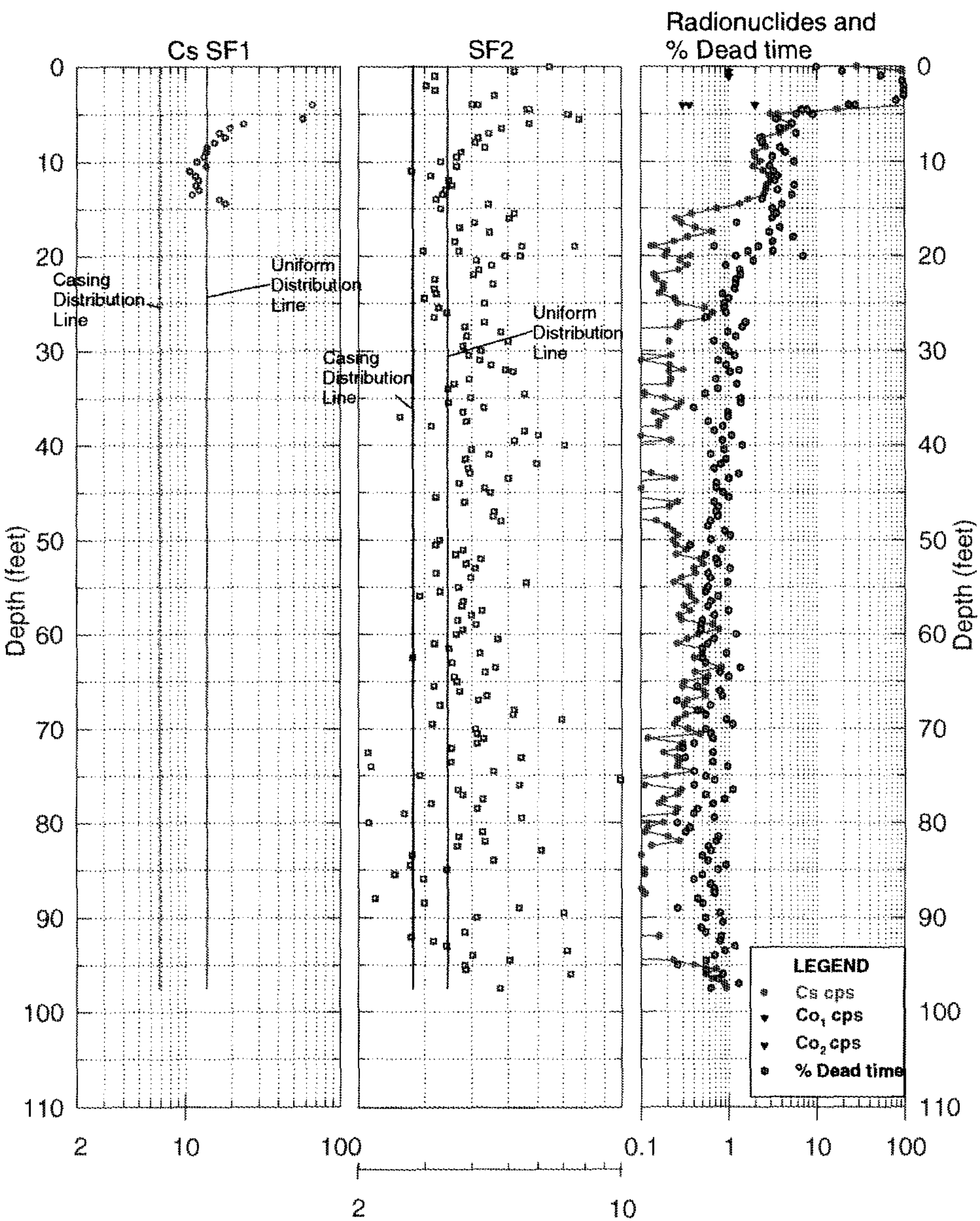
30-07-11
Natural Gamma Logs



30-07-11 Combination Plot



30-07-11
Shape Factor Analysis Logs



Spectral Gamma-Ray Borehole
Log Data Report

Log Event A

Borehole 30-07-10

Borehole Information

Farm : C
Tank : C-107
Site Number : 299-E27-92
N-Coord : 42,879
W-Coord : 48,515
TOC Elevation : 646.00
Water Level, ft : None
Date Drilled : 9/30/74

Casing Record

Type : Steel-welded
Thickness : 0.280
ID, in. : 6
Top Depth, ft. : 0
Bottom Depth, ft. : 100

Borehole Notes:
Borehole 30-07-10 was drilled in September 1974 to a depth of 100 ft with 6-in. casing. The casing thickness is presumed to be 0.280 in., on the basis of the published thickness for schedule-40, 6-in. steel tubing. No information concerning grouting or perforations was available; therefore, it is assumed that the borehole was not grouted or perforated. The top of the casing, which is the zero reference for the SGLS, is even with the ground surface.

Equipment Information

Logging System : 2
Detector Type : HPGe
Detector Efficiency : 35.0 %
Calibration Date : 10/96
Calibration Reference : GJO-HAN-13
Logging Procedure : P-GJPO-1783

Log Run Information

Log Run Number : 1
Log Run Date : 3/12/97
Logging Engineer: Bob Spatz
Start Depth, ft.: 98.5
Counting Time, sec.: 100
L/R : L
Shield : N
Finish Depth, ft. : 31.5
MSA Interval, ft. : 0.5
Log Speed, ft/min.: n/a

Log Run Number : 2
Log Run Date : 3/13/97
Logging Engineer: Bob Spatz
Start Depth, ft.: 32.5
Counting Time, sec.: 100
L/R : L
Shield : N
Finish Depth, ft. : 0.0
MSA Interval, ft. : 0.5
Log Speed, ft/min.: n/a

Log Run Number : 3
Log Run Date : 3/13/97
Logging Engineer: Bob Spatz
Start Depth, ft.: 40.0
Counting Time, sec.: 100
L/R : L
Shield : N
Finish Depth, ft. : 20.0
MSA Interval, ft. : 0.5
Log Speed, ft/min.: n/a

Log Event A

Borehole 30-07-10

Analysis Information

Analyst : D.L. Parker

Data Processing Reference : MAC-VZCP 1.7.9   Analysis Date : 8/20/97

Analysis Notes :

This borehole was logged by the SGLS in three log runs. One of the log runs was a relog of a previously logged section to provide an additional quality check. The pre- and post-survey field verification spectra met the acceptance criteria established for the peak shape and detector efficiency, confirming that the SGLS was operating within specifications. The energy calibration and peak-shape calibration from these spectra were used to establish the peak resolution and the channel-to-energy parameters used in processing the spectra acquired during the logging operation.

Casing correction factors for a 0.280-in.-thick steel casing were applied during analysis.

The only man-made radionuclide detected in this borehole was Cs-137. The presence of Cs-137 was measured continuously from the ground surface to 24 ft, 26 to 26.5 ft, 36 to 37 ft, and at 77.5 ft.

The U-238 concentration data are absent along several short intervals throughout the length of the borehole.

The K-40 and Th-232 concentrations increase at about 39.5 ft. K-40 concentrations are decreased from 42 to about 45 ft. Th-232 concentrations are highly variable over the depth of the borehole.

Shape factor data analysis was performed using the SGLS data from this borehole.

Additional information and interpretations of log data are included in the main body of the Tank Summary Data Reports for tanks C-107 and C-110.

Log Plot Notes:

Separate log plots show the man-made and the naturally occurring radionuclides. The natural radionuclides can be used for lithology interpretations. The headings of the plots identify the specific gamma rays used to calculate the concentrations.

Uncertainty bars on the plots show the statistical uncertainties for the measurements as 95-percent confidence intervals. Open circles on the plots give the MDL. The MDL of a radionuclide represents the lowest concentration at which positive identification of a gamma-ray peak is statistically defensible.

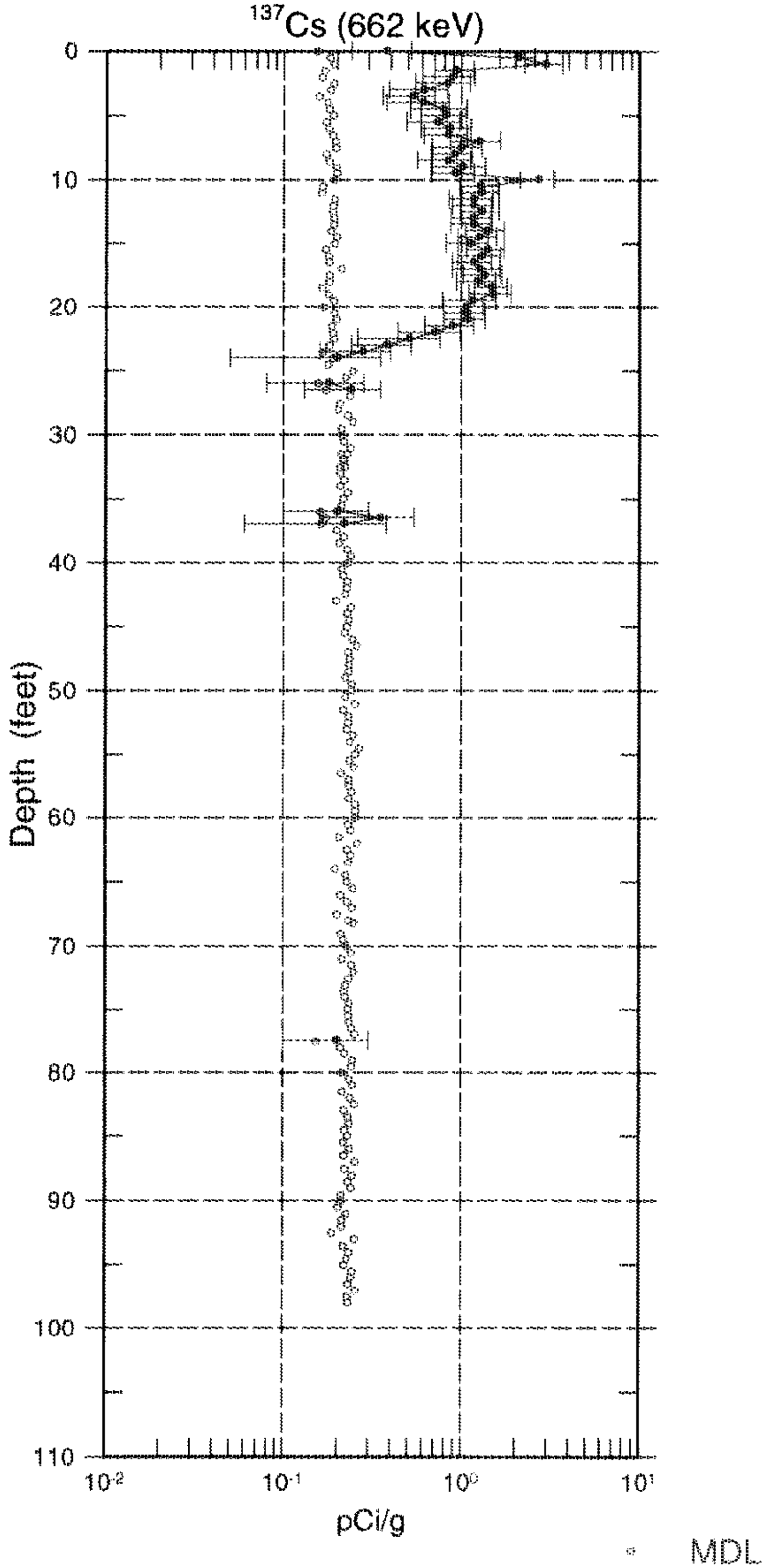
A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with the SGLS data.

A rerun plot presents data from the rerun log along with data from the original run to show the repeatability of the results.

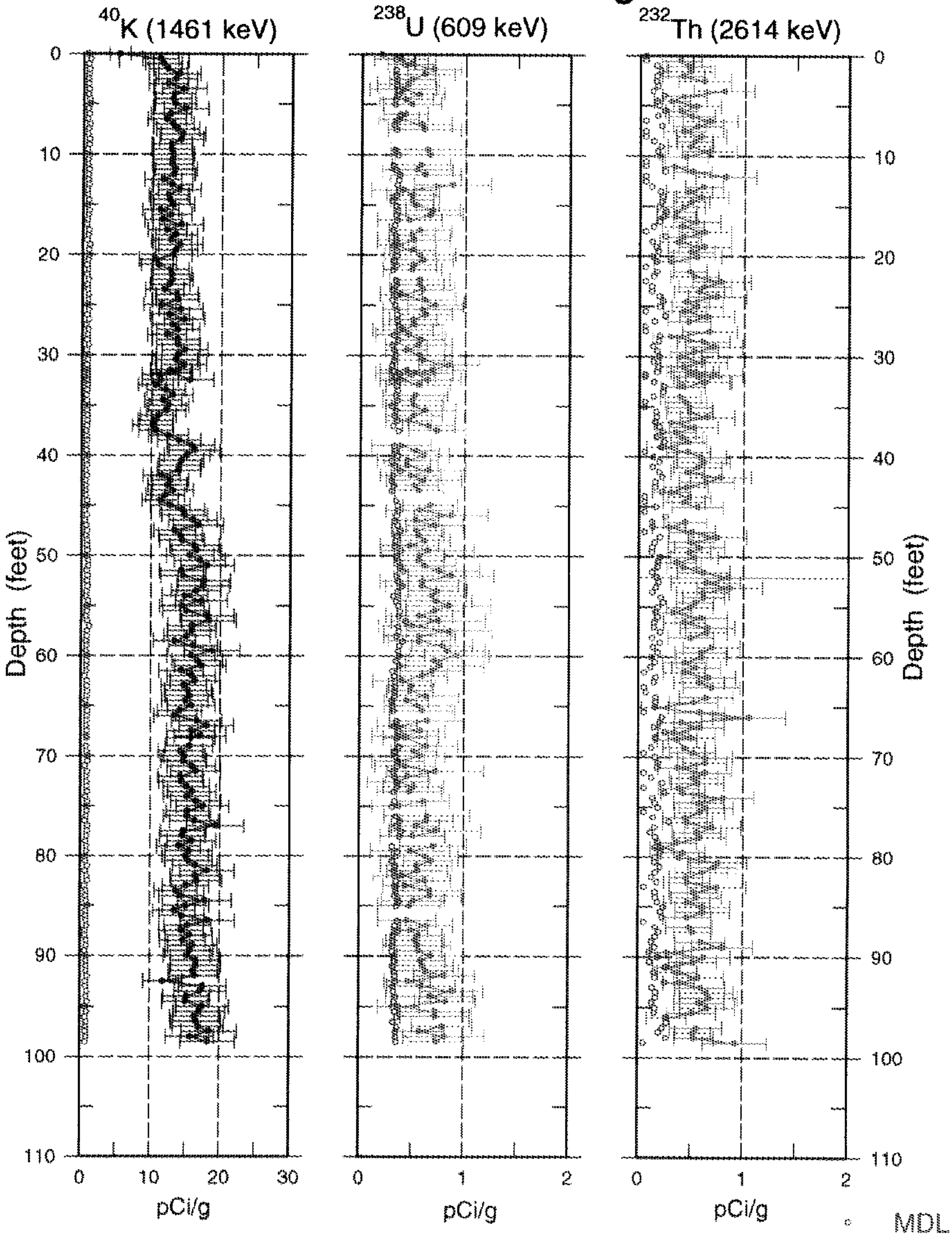
A plot showing the results of the shape factor analysis is included with the set of plots for this borehole.

30-07-10

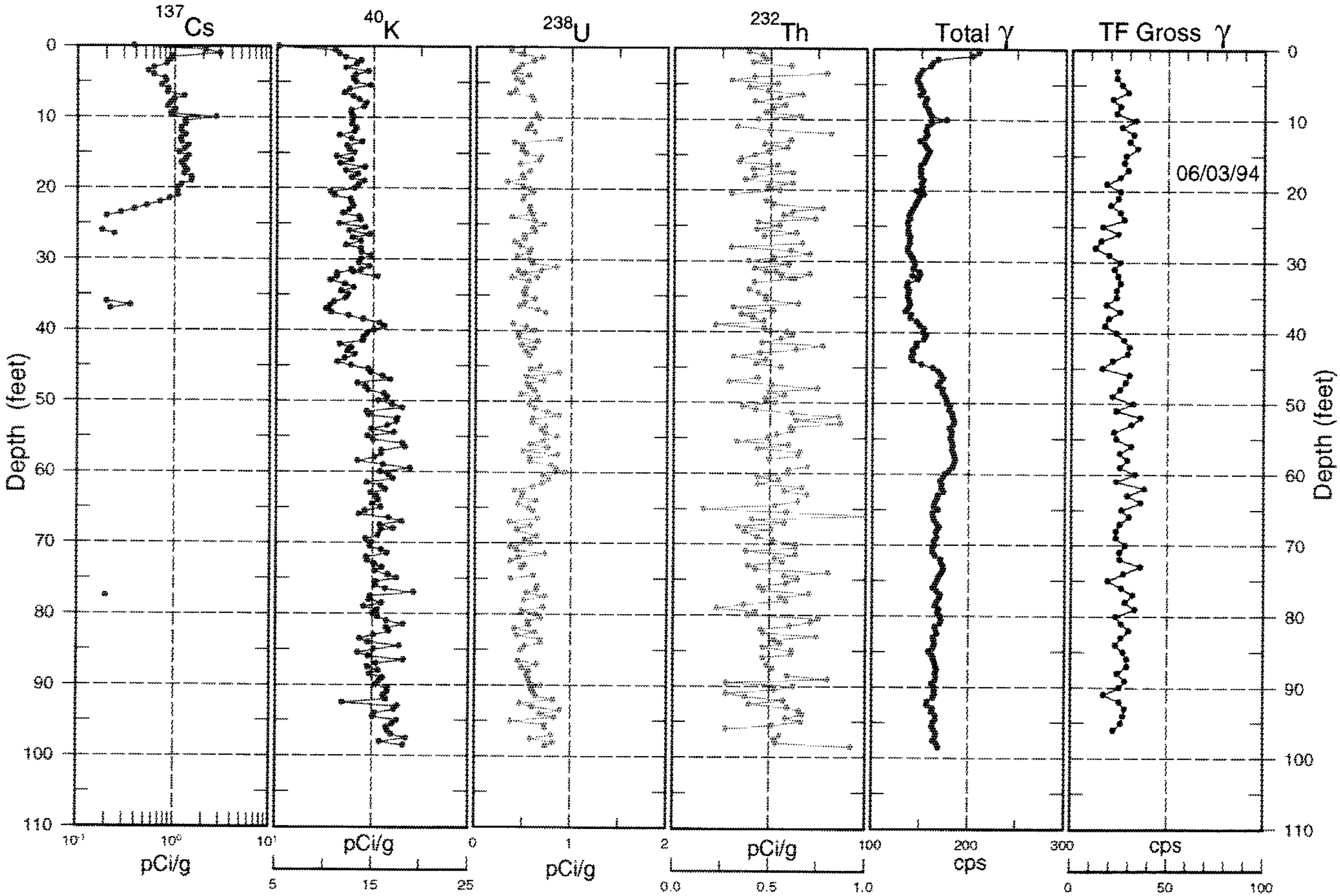
Man-Made Radionuclide Concentrations



30-07-10
Natural Gamma Logs

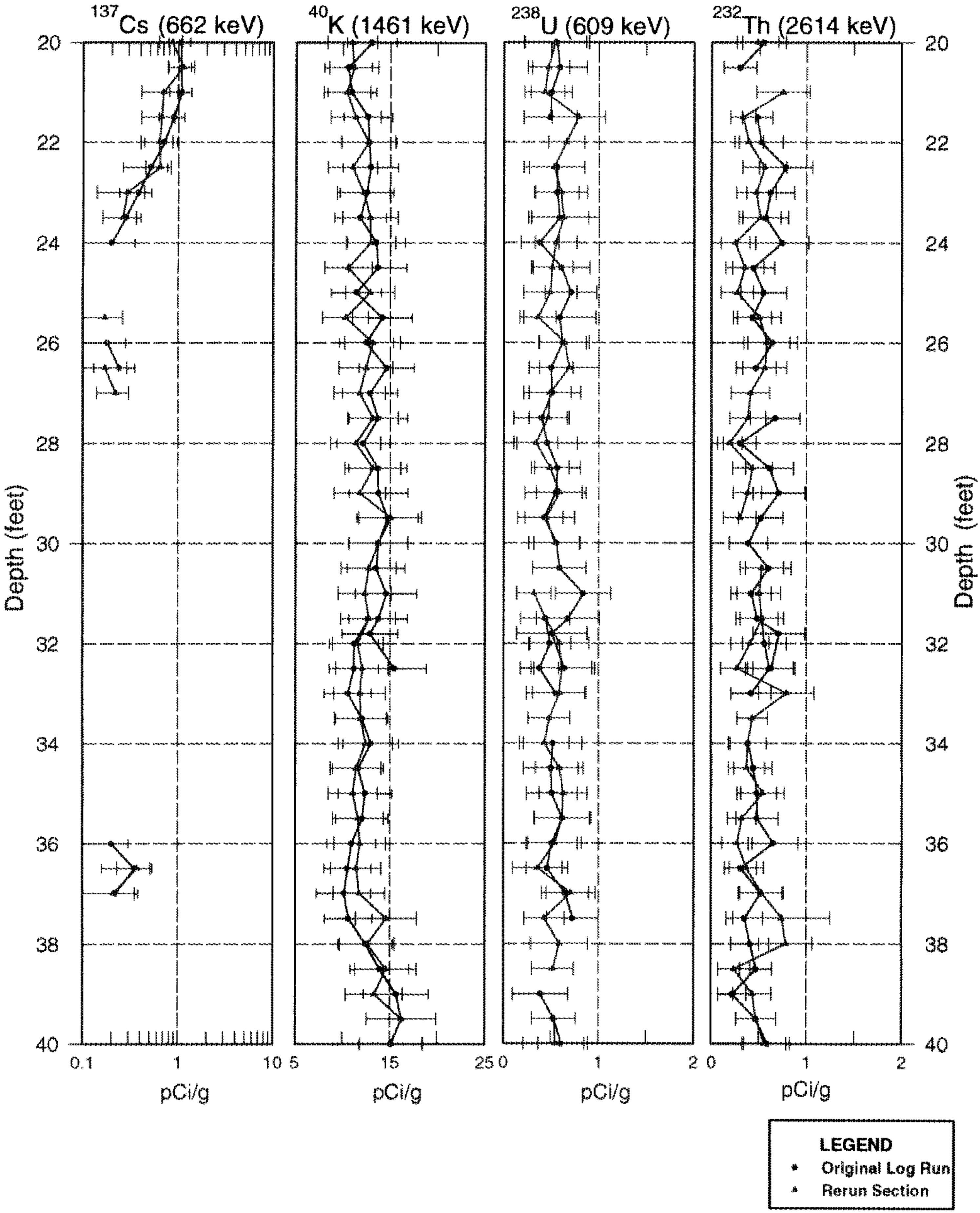


30-07-10 Combination Plot

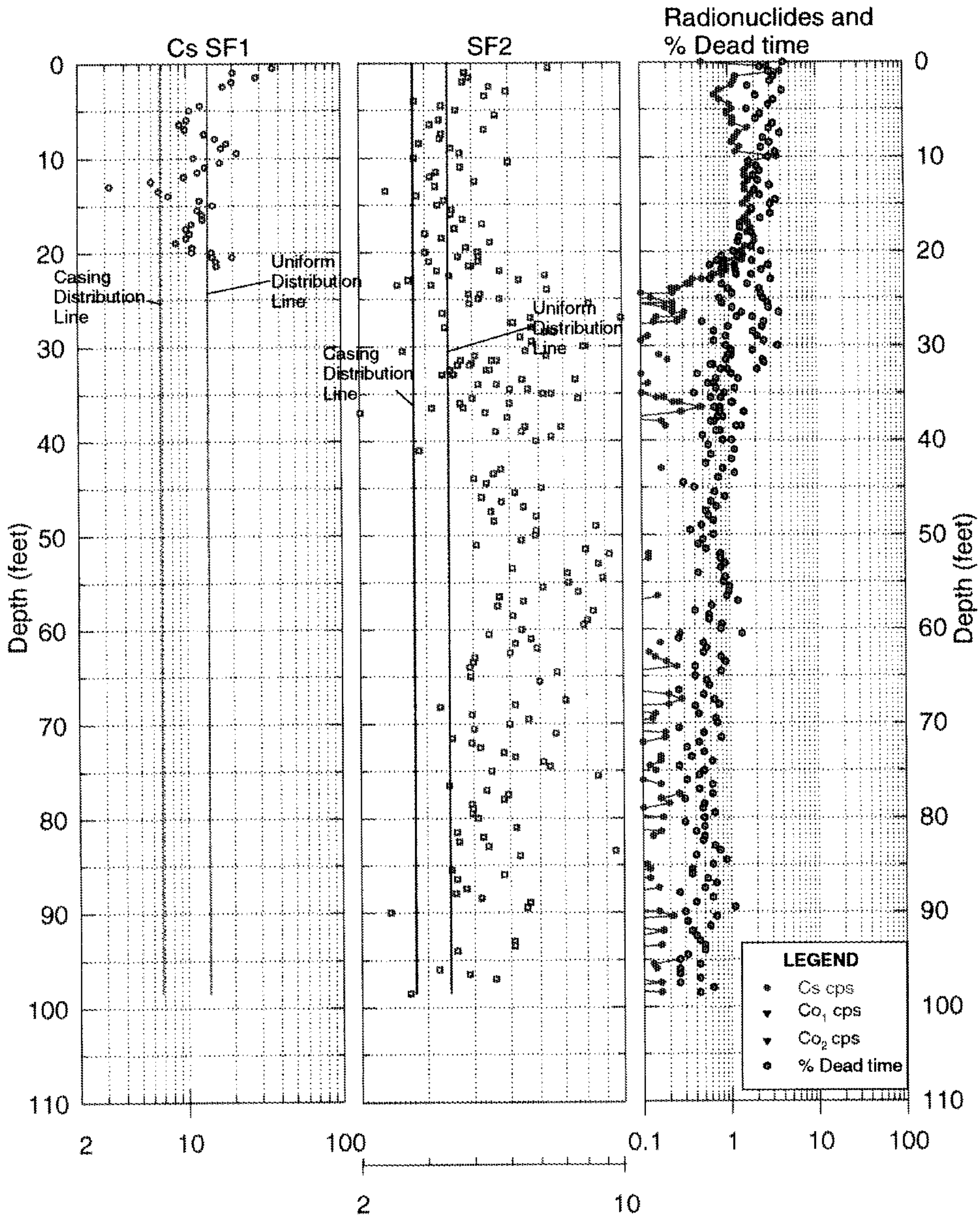


30-07-10

Rerun Section of the Man-Made and Natural Gamma Logs



30-07-10
Shape Factor Analysis Logs



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Spectral Gamma-Ray Borehole Log Data Report

Log Event A

Borehole 30-00-09

Borehole Information

Farm :	C	Tank :	C	Site Number :	299-E27-57
N-Coord :	42,889	W-Coord :	48,583	TOC Elevation :	653.46
Water Level, ft :	None	Date Drilled :	12/31/44		

Casing Record

Type :	Steel-welded	Thickness :	0.313	ID, in. :	8
Top Depth, ft. :	0	Bottom Depth, ft. :	150		

Borehole Notes:

Borehole 30-00-09 was drilled in December 1944 and completed to a depth of about 150 ft with 8-in. casing. No driller's log was available for this borehole to provide construction details. However, based on the date of construction, the borehole's location, borehole information presented in Chamness and Merz (1993), and the construction details from the field, it is believed that this borehole is similar in construction to boreholes 30-00-03 and 30-00-06. In boreholes 30-00-03 and 30-00-06, a string of 12-in. surface casing is present from just below the ground surface to a depth of about 54 to 58 ft. The 8-in. casing is assumed to be perforated from the bottom of the surface casing (at about 54 ft) to the bottom of the borehole with five perforations per foot. The bottom 8 in. of the borehole was probably grouted with cement.

The zero reference for the SGLS logs is the top of the 8-in. casing. This borehole is located on the side of a steep hill, and the top of the 8-in. casing is approximately 1 ft above the surface of the slope and approximately 11 ft above the tank farm ground surface. The current depth of the borehole, as verified with an electrical tape, is 58 ft. There is no information given as to when or how the bottom portion of the borehole was filled.

Equipment Information

Logging System :	2	Detector Type :	HPGe	Detector Efficiency :	35.0 %
Calibration Date :	10/96	Calibration Reference :	GJO-HAN-13	Logging Procedure :	P-GJPO-1783

Log Run Information

Log Run Number :	1	Log Run Date :	4/1/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	57.5	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	1.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Log Event A

Borehole 30-00-09

Analysis Information

Analyst : D.L. Parker

Data Processing Reference : MAC-VZCP 1.7.9 Analysis Date : 9/9/97

Analysis Notes :

This borehole was logged by the SGLS in one log run. The pre- and post-survey field verification spectra met the acceptance criteria established for the peak shape and detector efficiency, confirming that the SGLS was operating within specifications. The energy calibration and peak-shape calibration from these spectra were used to establish peak resolution and channel-to-energy parameters used in processing the spectra acquired during the logging operation. There was negligible gain drift during logging operations, and it was not necessary to adjust the established channel-to-energy parameters during processing of log data to maintain proper peak identification.

This borehole is probably double-cased from an unknown depth near the ground surface to about 58 ft. An appropriate casing correction factor for the double-cased portion of the borehole could not be applied because of the attenuation caused by the double-steel casings in this interval and the potential for grout between the two casings.

A casing correction factor for a 0.330-in.-thick casing was applied during the analysis of borehole data. This correction factor most closely matches the actual thickness of the 8-in. casing. Use of this casing correction factor will cause the radionuclide concentrations to be overestimated below the double-cased portion of the borehole and significantly underestimated in the double-cased portion of the borehole.

The top 1 ft of the borehole casing extends above the ground surface and was not logged.

Cs-137 was the only man-made radionuclide detected in this borehole. Cs-137 contamination was detected continuously from 1 to 3 ft.

The logs of the naturally occurring radionuclides show a decrease in KUT concentrations below 4 ft. An increase in K-40 concentrations was detected below 42 ft, and a decrease in K-40 concentrations was detected at about 57 ft.

Details concerning the interpretation of data for this borehole are presented in the Tank Summary Data Reports for tank C-110.

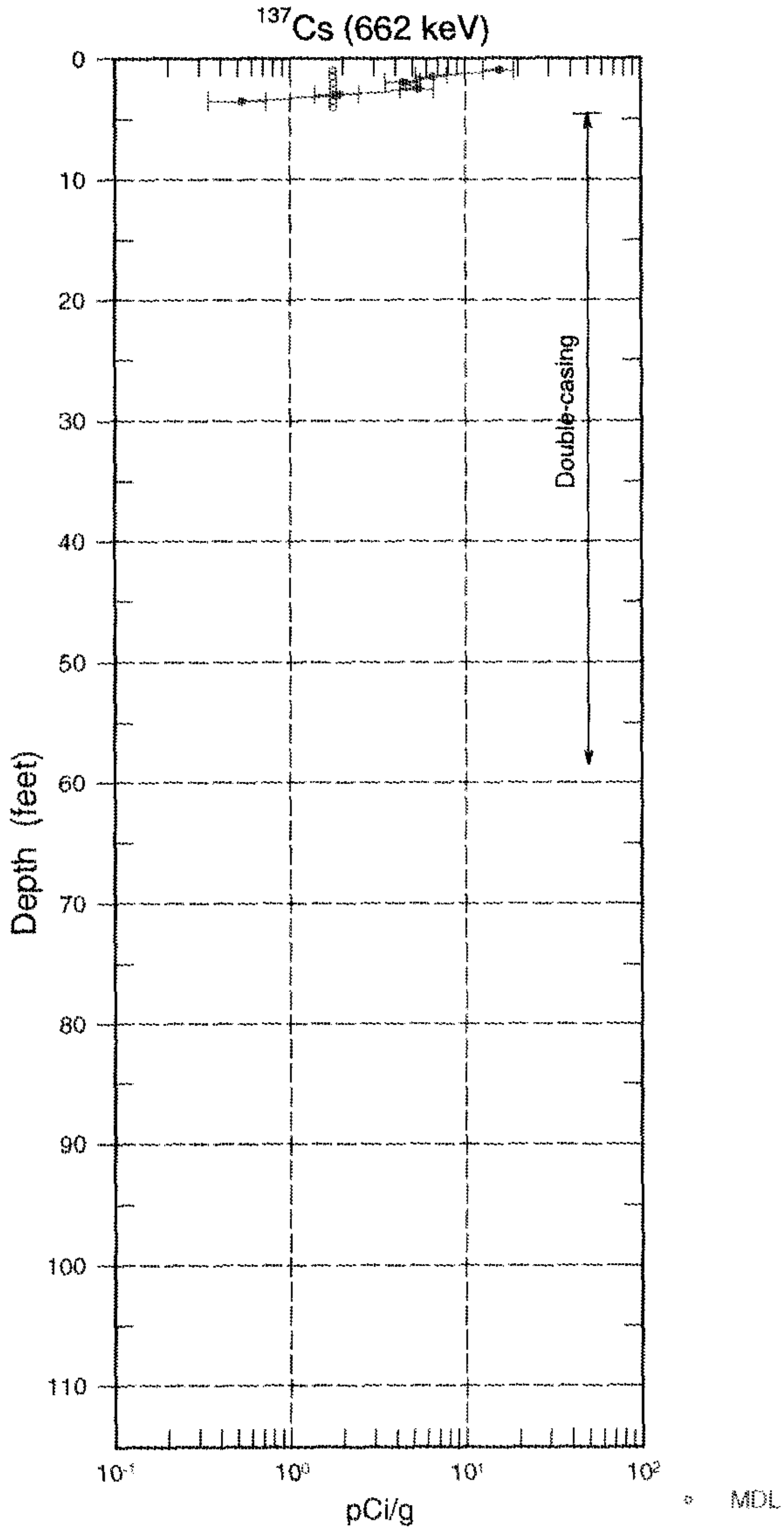
Log Plot Notes:

Separate log plots show the man-made and the naturally occurring radionuclides. The natural radionuclides can be used for lithology interpretations. The headings of the plots identify the specific gamma rays used to calculate the concentrations.

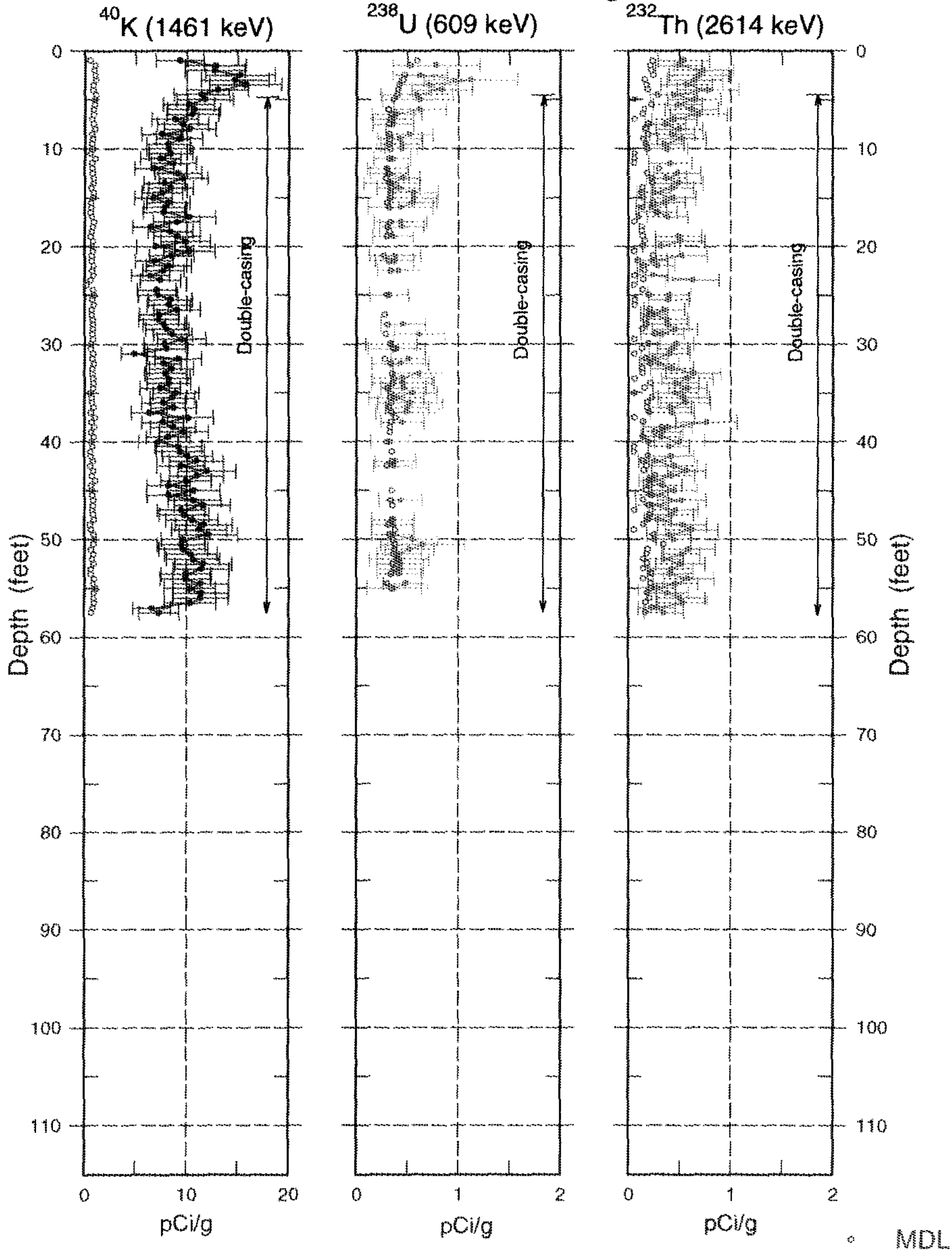
Uncertainty bars on the plots show the statistical uncertainties for the measurements as 95-percent confidence intervals. Open circles on the plots give the MDL. The MDL of a radionuclide represents the lowest concentration at which positive identification of a gamma-ray peak is statistically defensible.

A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with the SGLS data.

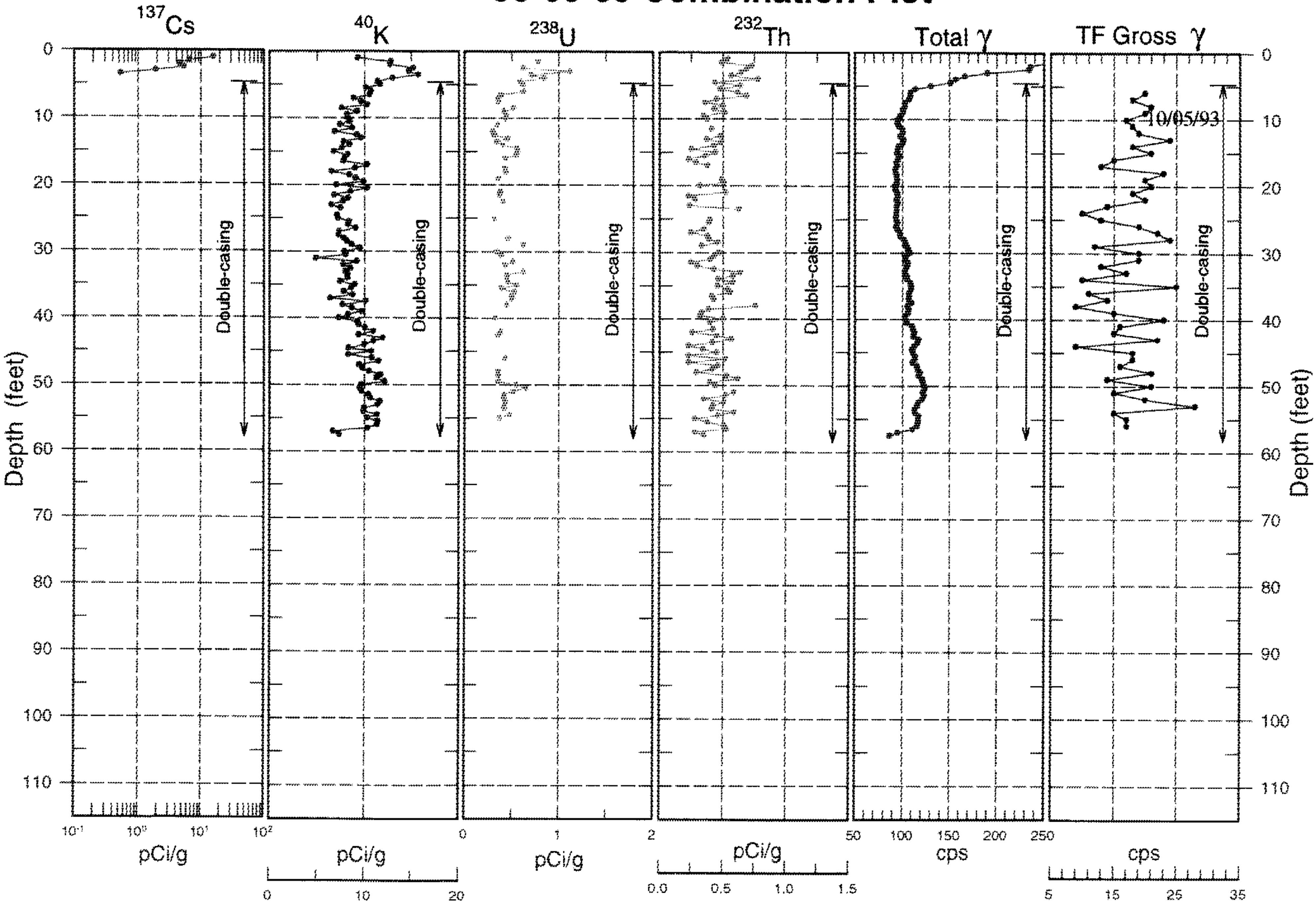
30-00-09
Man-Made Radionuclide Concentrations



30-00-09
Natural Gamma Logs



30-00-09 Combination Plot



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Spectral Gamma-Ray Borehole
Log Data Report

Log Event A

Borehole 30-10-09

Borehole Information

Farm : C | Tank : C-110 | Site Number : 299-E27-103
N-Coord : 42,926 | W-Coord : 48,585 | TOC Elevation : 646.00
Water Level, ft : None | Date Drilled : 9/30/74

Casing Record

Type : Steel-welded | Thickness : 0.280 | ID, in. : 6
Top Depth, ft. : 0 | Bottom Depth, ft. : 100

Borehole Notes:
Borehole 30-10-09 was drilled in September 1974 to a depth of 100 ft with 6-in. casing. The casing thickness is presumed to be 0.280 in., on the basis of the published thickness for schedule-40, 6-in. steel tubing. No information concerning grouting or perforations was available; therefore, it is assumed that the borehole was not grouted or perforated. The top of the casing, which is the zero reference for the SGLS, is even with the ground surface. The borehole is located on a slope and is about 5 ft above the ground surface of the tank farm.

Equipment Information

Logging System : 2 | Detector Type : HPGe | Detector Efficiency : 35.0 %
Calibration Date : 10/96 | Calibration Reference : GJO-HAN-13 | Logging Procedure : P-GJPO-1783

Log Run Information

Log Run Number : 1 | Log Run Date : 2/28/97 | Logging Engineer: Bob Spatz
Start Depth, ft.: 0.0 | Counting Time, sec.: 100 | L/R : L | Shield : N
Finish Depth, ft. : 18.0 | MSA Interval, ft. : 0.5 | Log Speed, ft/min.: n/a

Log Run Number : 2 | Log Run Date : 2/28/97 | Logging Engineer: Bob Spatz
Start Depth, ft.: 97.5 | Counting Time, sec.: 100 | L/R : L | Shield : Y
Finish Depth, ft. : 50.5 | MSA Interval, ft. : 0.5 | Log Speed, ft/min.: n/a

Log Run Number : 3 | Log Run Date : 3/4/97 | Logging Engineer: Bob Spatz
Start Depth, ft.: 51.5 | Counting Time, sec.: 100 | L/R : L | Shield : N
Finish Depth, ft. : 17.0 | MSA Interval, ft. : 0.5 | Log Speed, ft/min.: n/a

Analysis Information

Analyst : D.L. Parker

Data Processing Reference : MAC-VZCP 1.7.9 Analysis Date : 9/9/97

Analysis Notes :

This borehole was logged by the SGLS in three log runs. The pre- and post-survey field verification spectra met the acceptance criteria established for the peak shape and detector efficiency, confirming that the SGLS was operating within specifications. The energy calibration and peak-shape calibration from these spectra were used to establish the peak resolution and the channel-to-energy parameters used in processing the spectra acquired during the logging operation.

Casing correction factors for a 0.280-in.-thick steel casing were applied during analysis.

Shape factor analysis, a data analysis method developed as part of the Hanford Tank Farms Vadose Zone Project, was performed on SGLS data from this borehole, but Cs-137 concentrations were too low to produce meaningful results.

The only man-made radionuclide detected in this borehole was Cs-137. The presence of Cs-137 was measured intermittently from the ground surface to 13.5 ft and almost continuously from 17 to 37.5 ft. The K-40 concentrations increase to a background of about 18 pCi/g at 41 ft and remain elevated to about 51 ft. K-40 concentrations decrease to about 16 pCi/g at about 51 ft and remain at this concentration to the bottom of the borehole.

Additional information and interpretations of log data are included in the main body of the Tank Summary Data Report for tank C-110.

Log Plot Notes:

Separate log plots show the man-made and the naturally occurring radionuclides. The natural radionuclides can be used for lithology interpretations. The headings of the plots identify the specific gamma rays used to calculate the concentrations.

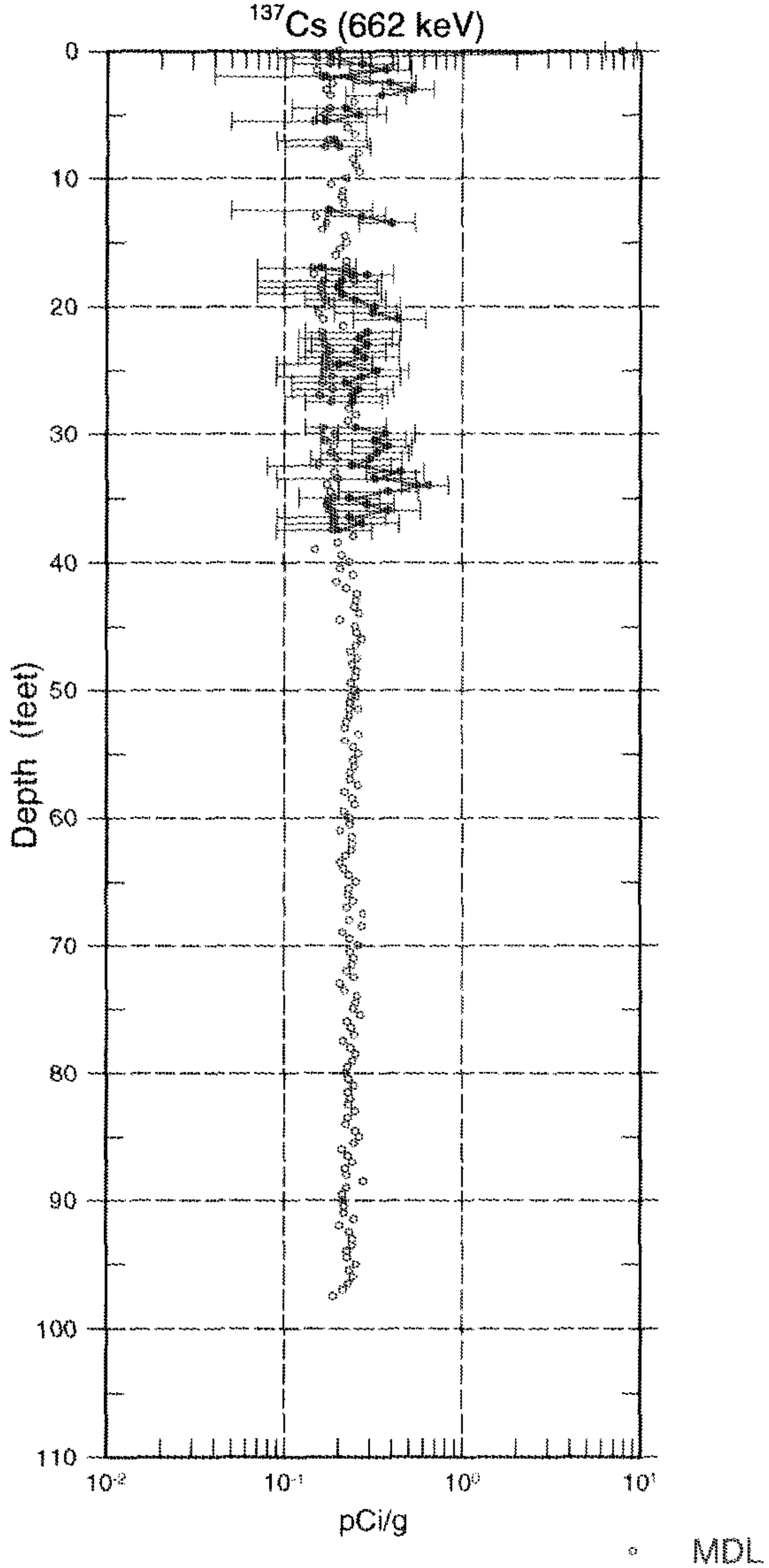
Uncertainty bars on the plots show the statistical uncertainties for the measurements as 95-percent confidence intervals. Open circles on the plots give the MDL. The MDL of a radionuclide represents the lowest concentration at which positive identification of a gamma-ray peak is statistically defensible.

A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with the SGLS data.

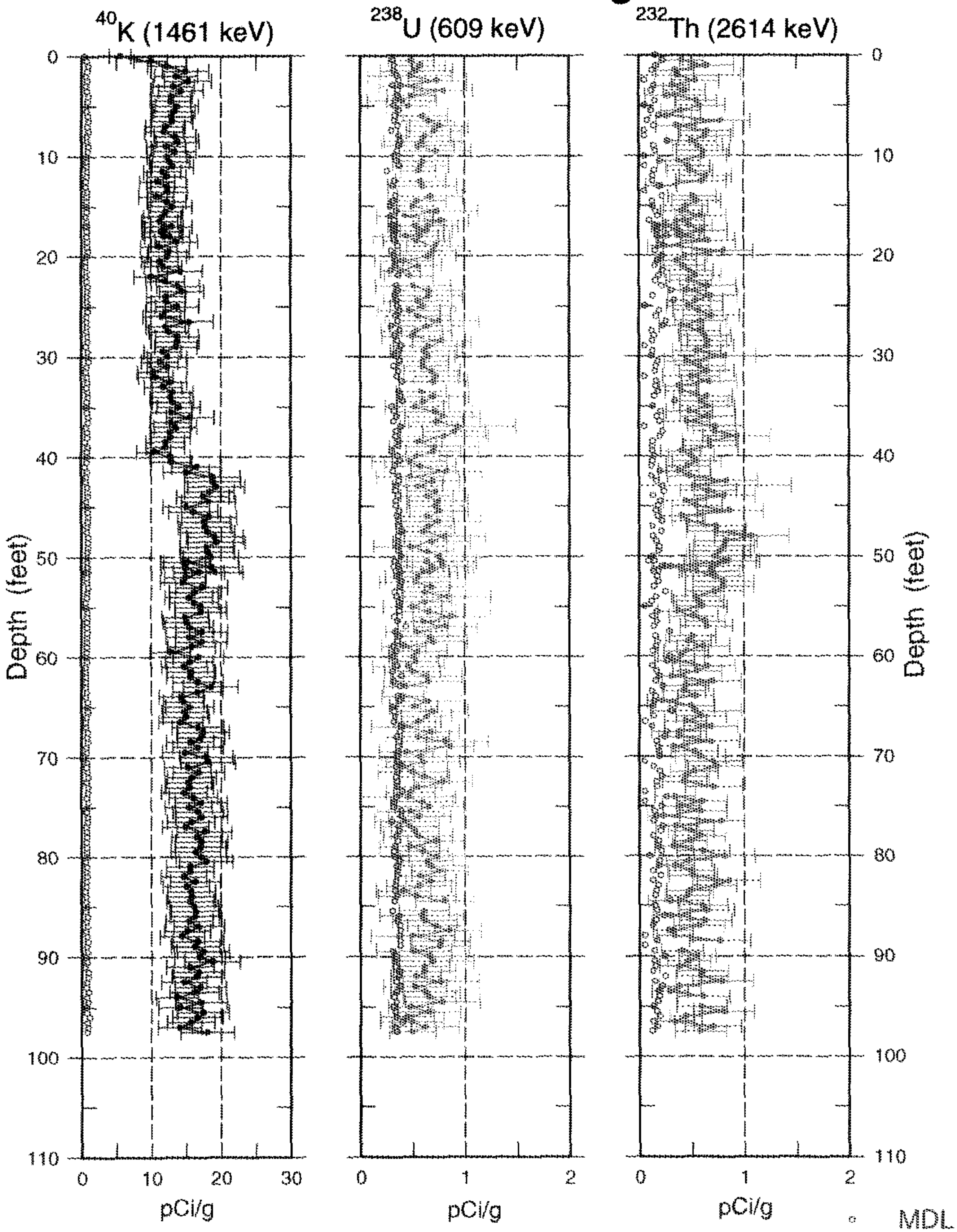
A plot of representative historical gross gamma-ray logs from 1975 to 1983 is included.

30-10-09

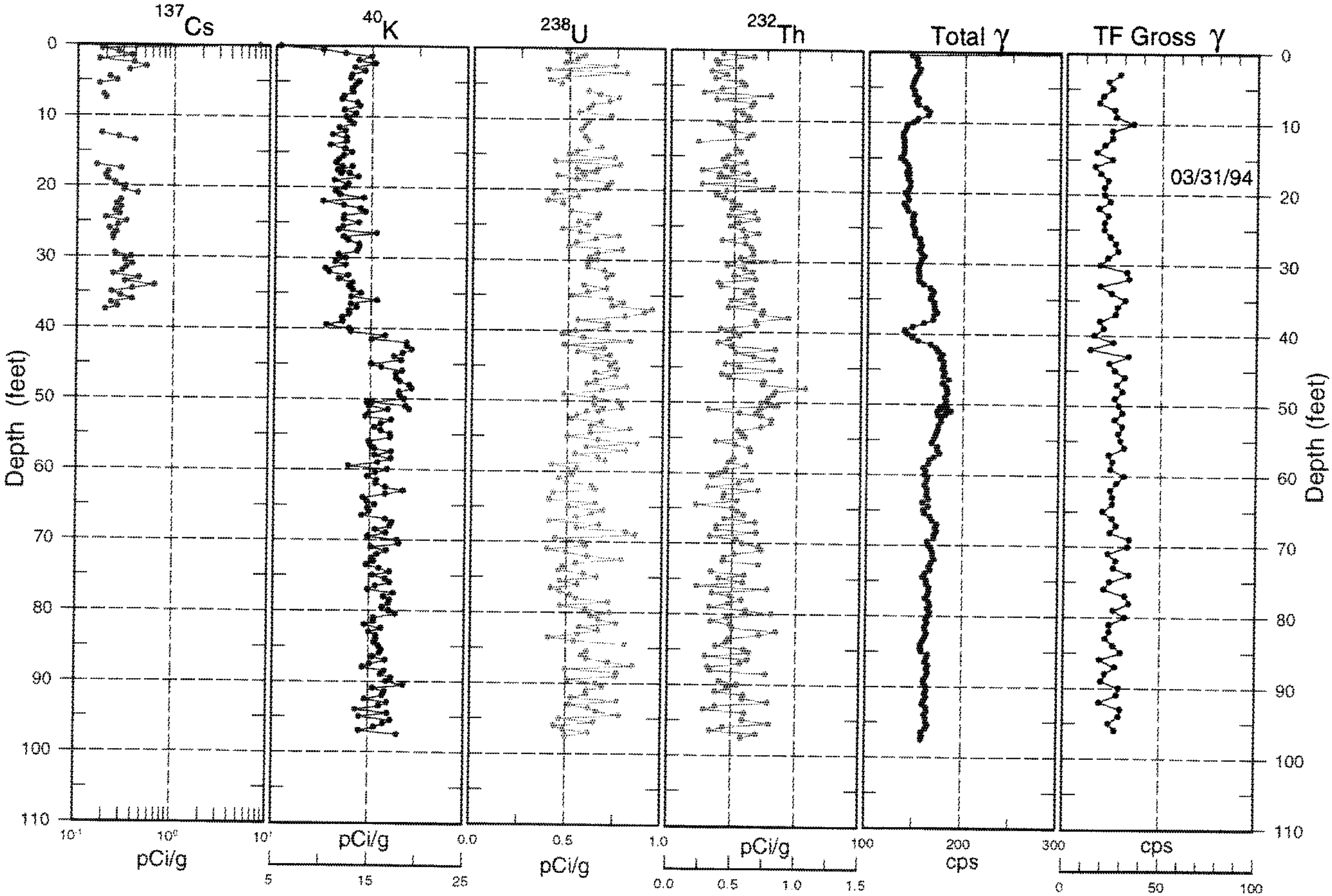
Man-Made Radionuclide Concentrations



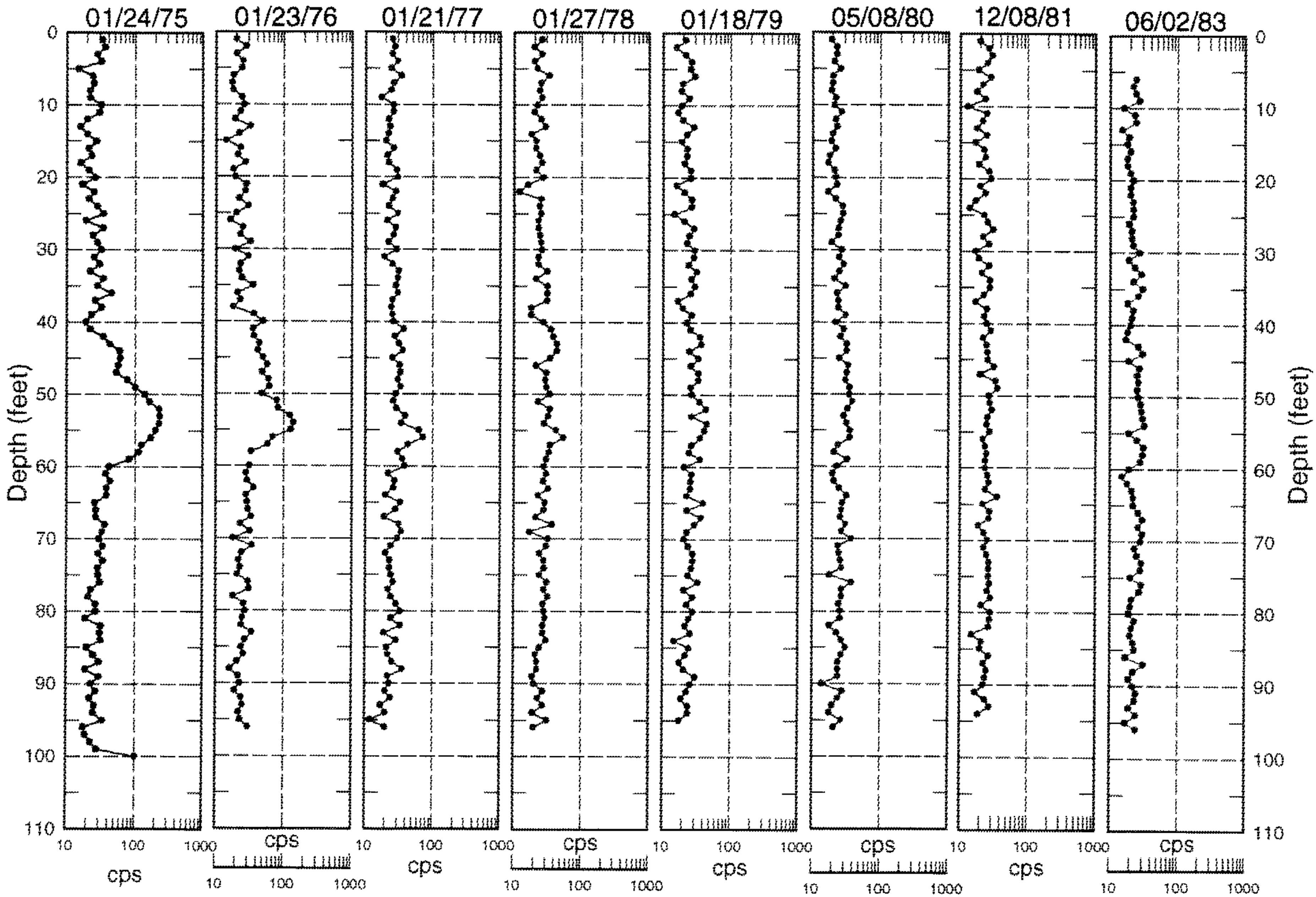
30-10-09
Natural Gamma Logs



30-10-09 Combination Plot



Historical Gross Gamma Logs for Borehole 30-10-09



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Spectral Gamma-Ray Borehole
Log Data Report

Log Event A

Borehole 30-10-11

Borehole Information

Farm :	C	Tank :	C-110	Site Number :	299-E27-104
N-Coord :	42,967	W-Coord :	48,570	TOC Elevation :	646.00
Water Level, ft :	None	Date Drilled :	4/30/75		

Casing Record

Type :	Steel-welded	Thickness :	0.280	ID, in. :	6
Top Depth, ft. :	0	Bottom Depth, ft. :	100		

Borehole Notes:
Borehole 30-10-11 was drilled in April 1975 to a depth of 100 ft with 6-in. casing. The casing thickness is presumed to be 0.280 in., on the basis of the published thickness for schedule-40, 6-in. steel tubing. No information concerning grouting or perforations was available; therefore, it is assumed that the borehole was not grouted or perforated. The top of the casing, which is the zero reference for the SGLS, is even with the ground surface.

Equipment Information

Logging System :	2	Detector Type :	HPGe	Detector Efficiency :	35.0 %
Calibration Date :	10/96	Calibration Reference :	GJO-HAN-13	Logging Procedure :	P-GJPO-1783

Log Run Information

Log Run Number :	1	Log Run Date :	3/5/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	0.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	16.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Log Run Number :	2	Log Run Date :	3/5/97	Logging Engineer:	Alan Pearson		
Start Depth, ft.:	98.5	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	15.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Log Run Number :	3	Log Run Date :	3/7/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	50.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	30.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Analysis Information

Analyst : D.L. Parker

Data Processing Reference : MAC-VZCP 1.7.9 Analysis Date : 9/9/97

Analysis Notes :

This borehole was logged by the SGLS in three log runs. One of the log runs was a relog of a previously logged section to provide an additional quality check. The pre- and post-survey field verification spectra met the acceptance criteria established for the peak shape and detector efficiency, confirming that the SGLS was operating within specifications. The energy calibration and peak-shape calibration from these spectra were used to establish the peak resolution and the channel-to-energy parameters used in processing the spectra acquired during the logging operation. There was slight gain drift during the relog run, and it was necessary to adjust the established channel-to-energy parameters to maintain proper peak identification.

Casing correction factors for a 0.280-in.-thick steel casing were applied during analysis.

Shape factor analysis, a data analysis method developed as part of the Hanford Tank Farms Vadose Zone Project, was performed on SGLS data from this borehole.

The only man-made radionuclide detected in this borehole was Cs-137. The presence of Cs-137 was measured continuously from the ground surface to 3.5 ft.

The K-40 concentrations increase at about 43.5 ft and remain elevated to the bottom of the borehole. A gradual increase in K-40 concentrations was detected from about 70 to 90 ft.

Th-232 concentrations increase at about 43.5 ft and remain elevated to about 60 ft. Th-232 concentrations decrease sharply at about 60 ft and are highly variable over the depth of the borehole.

Additional information and interpretations of log data are included in the main body of the Tank Summary Data Report for tank C-110.

Log Plot Notes:

Separate log plots show the man-made and the naturally occurring radionuclides. The natural radionuclides can be used for lithology interpretations. The headings of the plots identify the specific gamma rays used to calculate the concentrations.

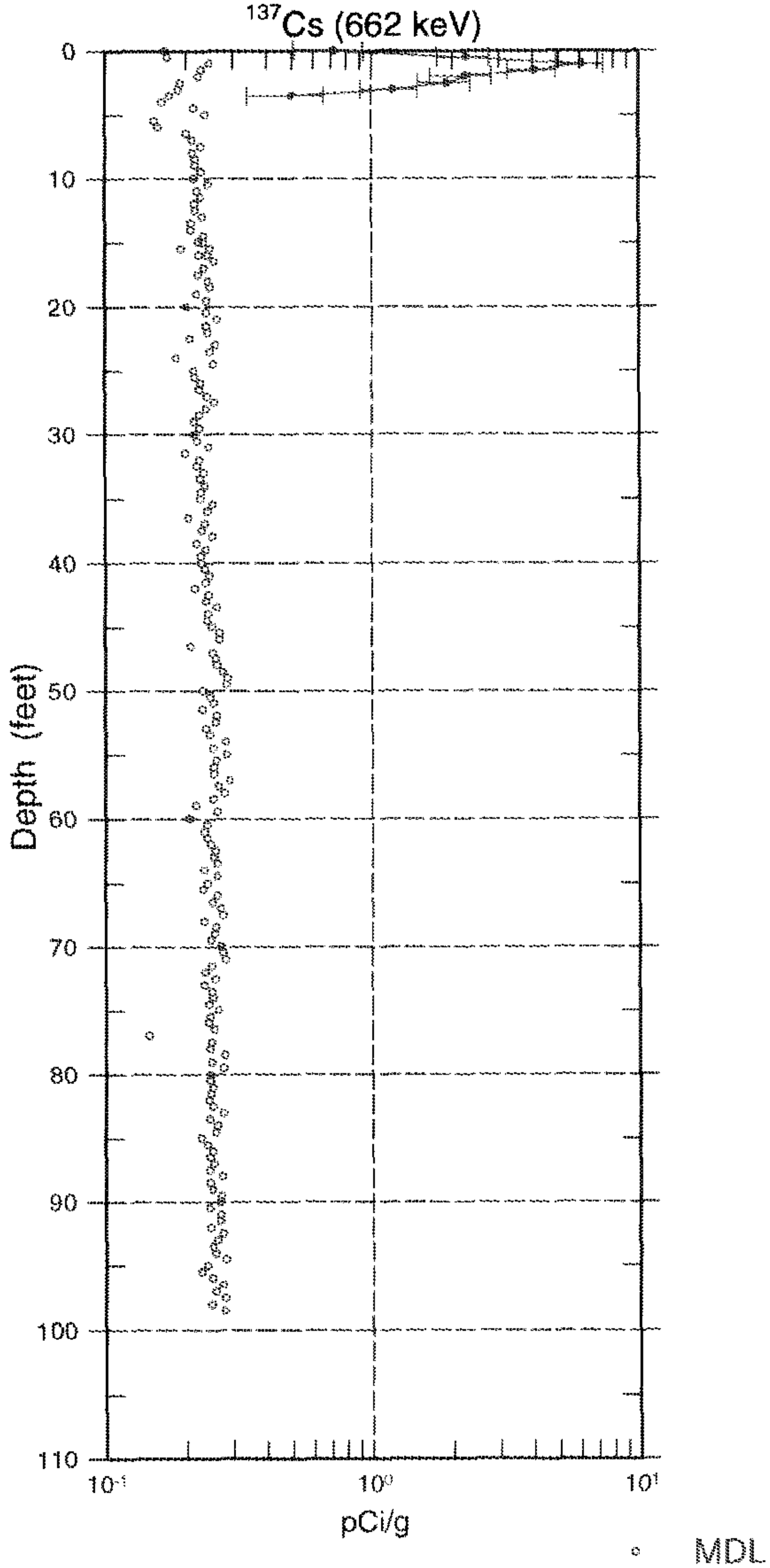
Uncertainty bars on the plots show the statistical uncertainties for the measurements as 95-percent confidence intervals. Open circles on the plots give the MDL. The MDL of a radionuclide represents the lowest concentration at which positive identification of a gamma-ray peak is statistically defensible.

A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with the SGLS data.

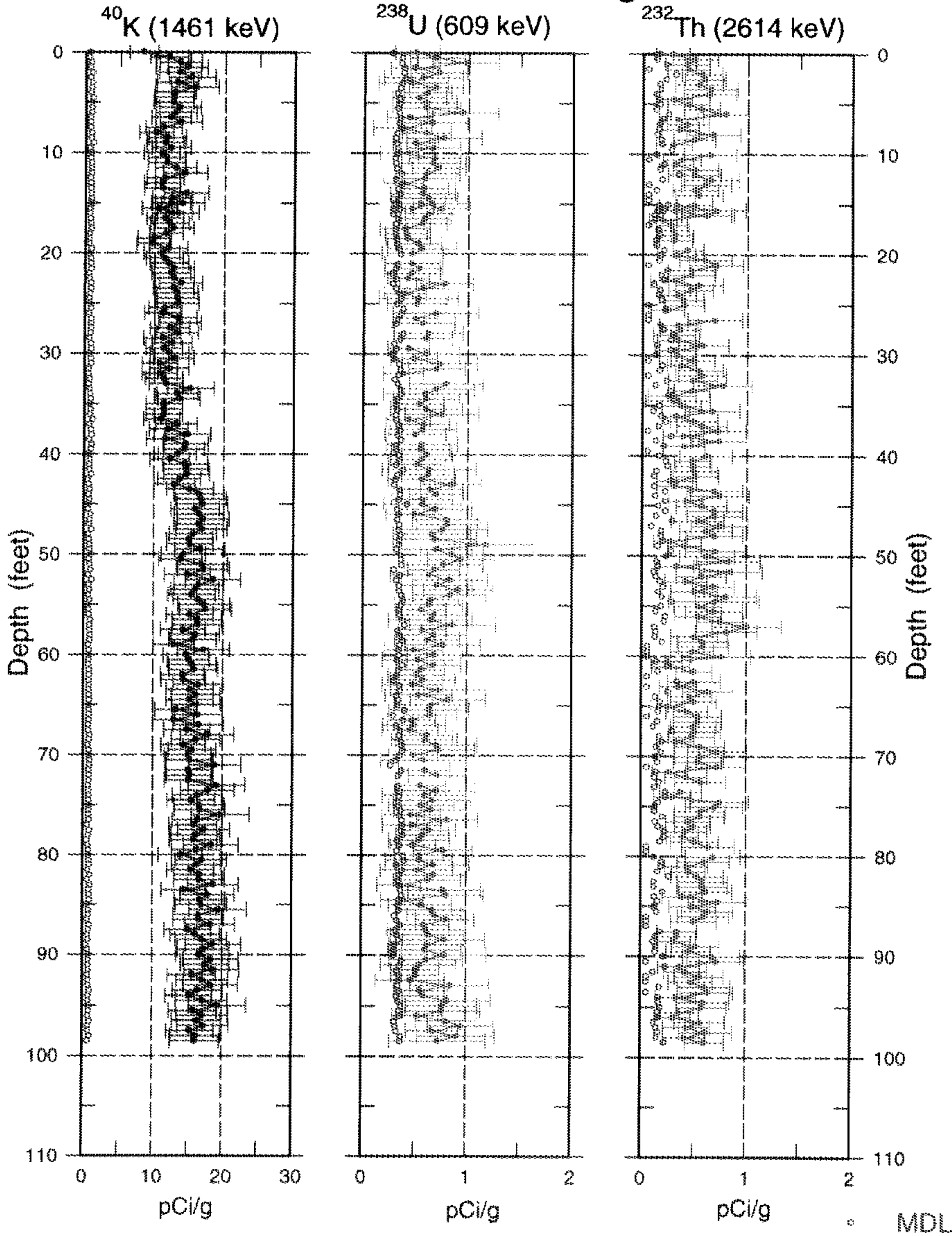
A rerun plot that presents data from the rerun log along with data from the original run to show the repeatability of the results.

A plot of the results of the shape factor analysis for the distribution of gamma-ray energies for this borehole is included.

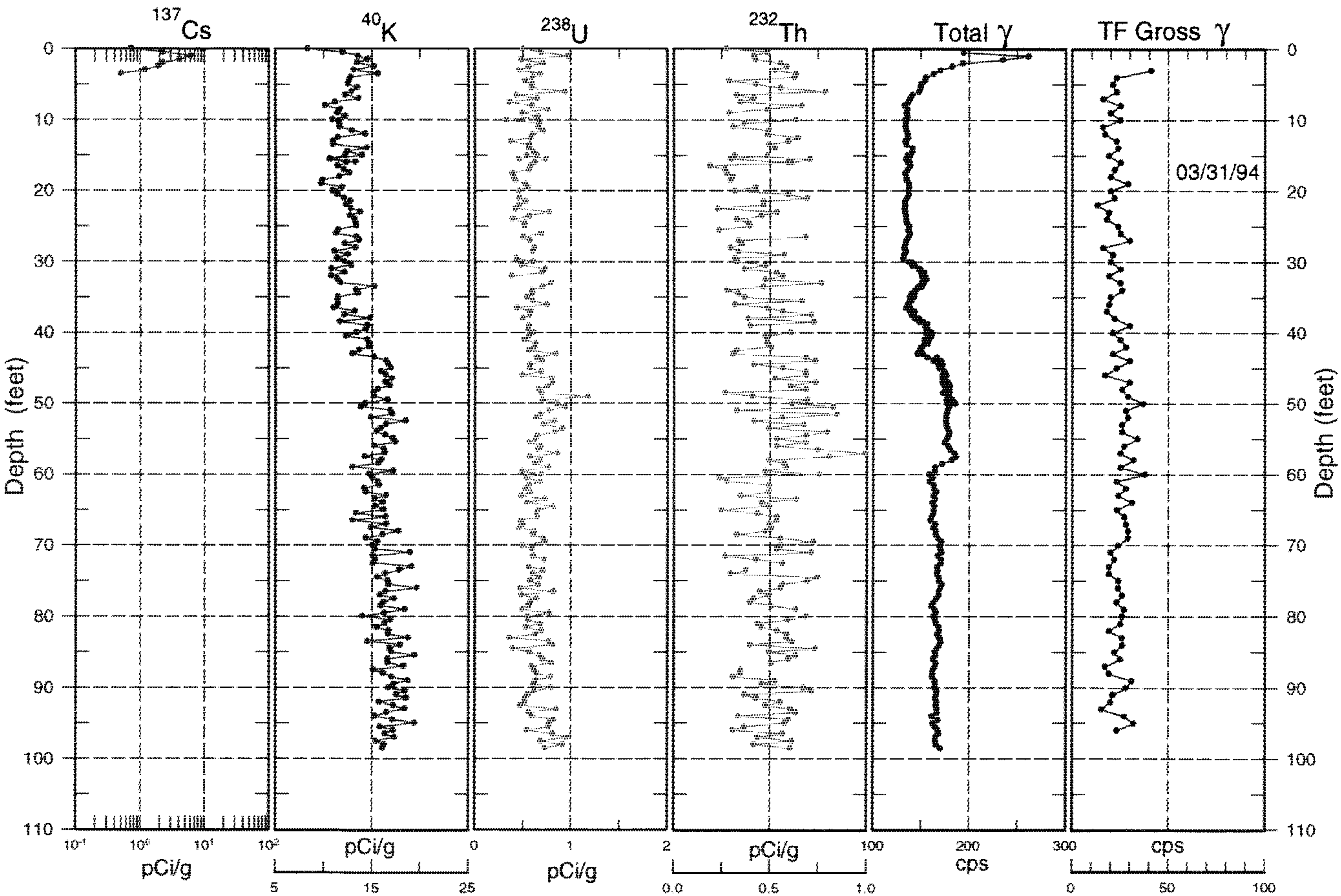
30-10-11
Man-Made Radionuclide Concentrations



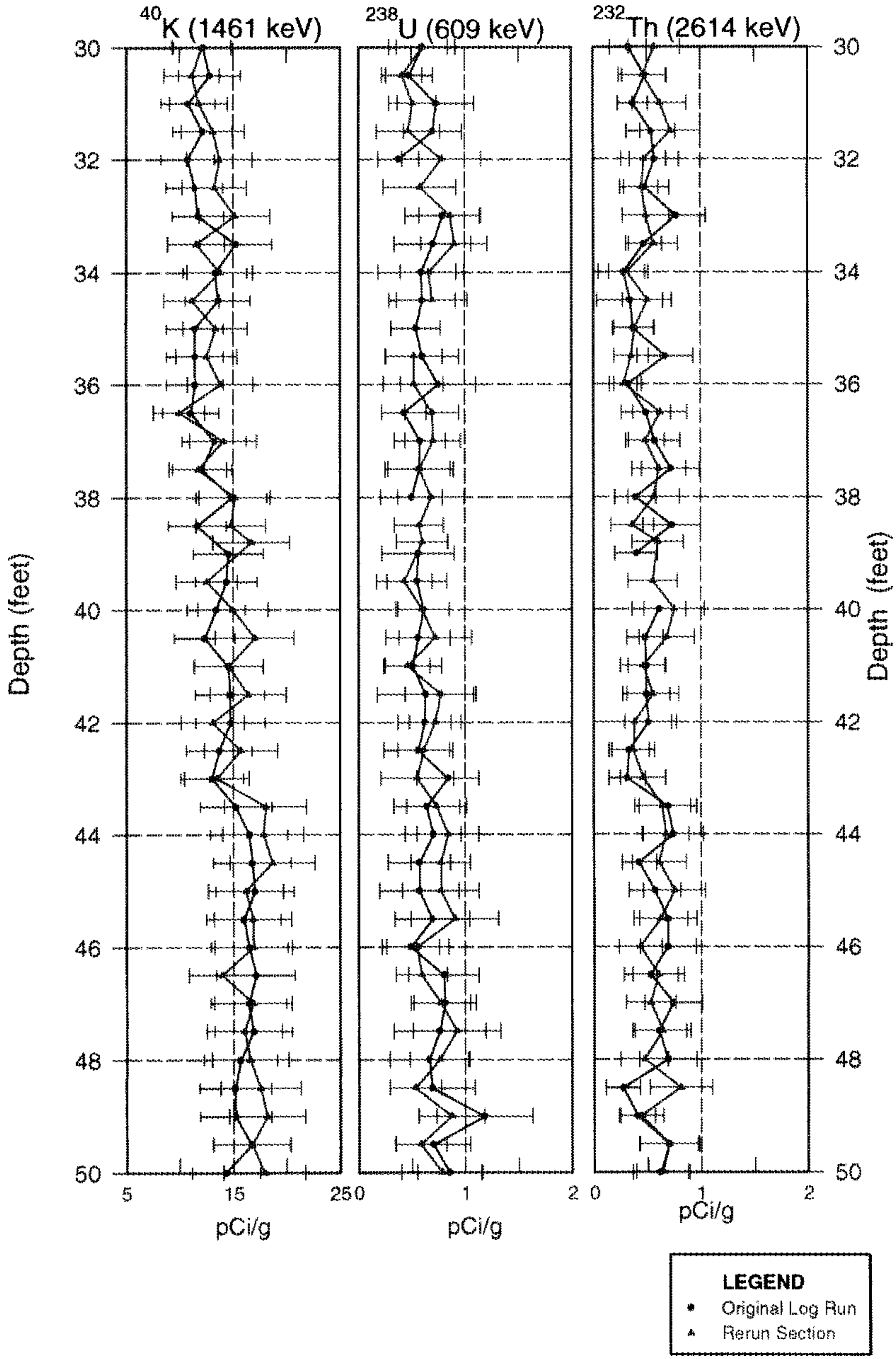
30-10-11
Natural Gamma Logs



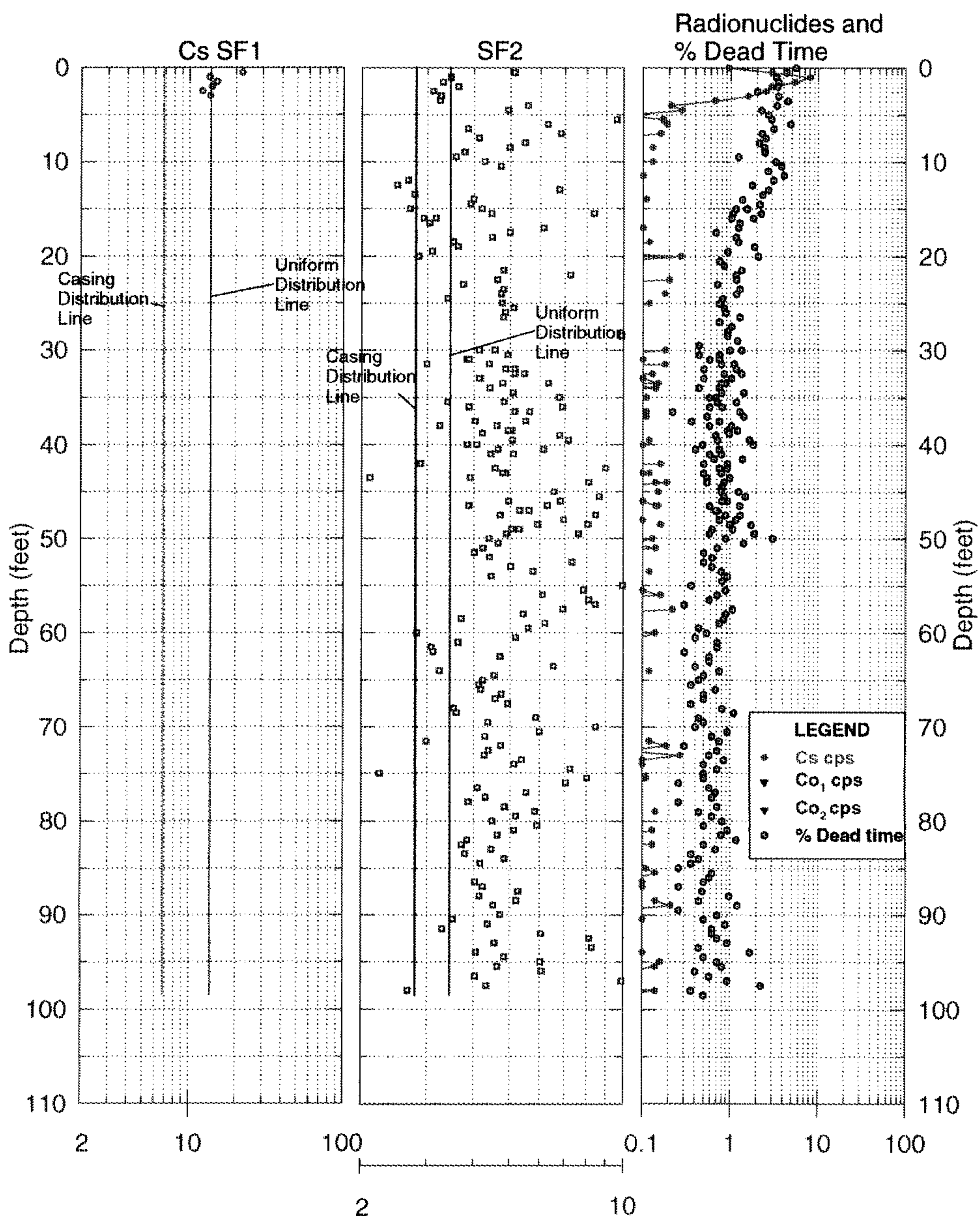
30-10-11 Combination Plot



30-10-11
Rerun Section of Natural Gamma Logs



30-10-11
Shape Factor Analysis Logs



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Spectral Gamma-Ray Borehole
Log Data Report

Log Event A

Borehole 30-00-22

Borehole Information

Farm :	C	Tank :	C	Site Number :	299-E27-120
N-Coord :	42,770	W-Coord :	48,760	TOC Elevation :	Unknown
Water Level, ft :	None	Date Drilled :	3/31/77		

Casing Record

Type :	Steel-welded	Thickness :	0.280	ID, in. :	6
Top Depth, ft. :	0	Bottom Depth, ft. :	60		

Cement Bottom, ft. : 60 Cement Top, ft. : 0

Borehole Notes:

Borehole 30-00-22 was drilled in March 1977 to a depth of 60 ft with 6-in. casing. The casing thickness is presumed to be 0.280 in., on the basis of the published thickness for schedule-40, 6-in. steel tubing. No driller's log is available for this borehole so construction details from Chamness and Merz (1993) were used in preparing this report. Chamness and Merz (1993) note that the borehole casing was grouted, but give no details as to which interval(s) were grouted or how much grout was used. No mention is made of perforations and it is therefore assumed that the borehole casing was not perforated.

The top of the casing, which is the zero reference for the SGLS, is approximately 1 ft above the ground surface. The top 1 ft of the borehole was not logged. The total logging depth achieved by the SGLS was 54.0 ft.

Equipment Information

Logging System :	2	Detector Type :	HPGe	Detector Efficiency :	35.0 %
Calibration Date :	10/96	Calibration Reference :	GJO-HAN-13	Logging Procedure :	P-GJPO-1783

Log Run Information

Log Run Number :	1	Log Run Date :	4/4/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	54.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	8.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Log Run Number :	2	Log Run Date :	4/8/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	9.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	1.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Log Event A

Borehole 30-00-22

Analysis Information

Analyst : D.L. Parker

Data Processing Reference : MAC-VZCP 1.7.9 Analysis Date : 10/29/97

Analysis Notes :

This borehole was logged by the SGLS in two log runs. The pre- and post-survey field verification spectra met the acceptance criteria established for the peak shape and detector efficiency, confirming that the SGLS was operating within specifications. The energy calibration and peak-shape calibration from these spectra were used to establish the peak resolution and channel-to-energy parameters used in processing the spectra acquired during the logging operation. No fine gain adjustments were necessary during logging of this borehole.

Casing correction factors for a 0.280-in.-thick steel casing were applied during analysis.

The man-made radionuclide Cs-137 was detected around this borehole. The presence of Cs-137 was detected almost continuously from the ground surface to 18 ft. A well-defined peak occurs at about 6 to 10 ft with a maximum Cs-137 concentration of about 860 pCi/g at 8 ft. A zone of lower Cs-137 concentrations occurs from about 10 to 18 ft.

K-40 concentrations increase steadily from 1 to about 3.5 ft, reaching a concentration of about 12.5 pCi/g, and then decrease sharply to about 8.4 pCi/g at about 6.5 ft. K-40 concentrations then increase to about 12 pCi/g from about 7 to 8.5 ft, decrease to less than 10 pCi/g from about 9 to 10.5 ft, and then increase to about 13 pCi/g from about 11.5 to 14 ft. K-40 concentrations decrease sharply at about 15 ft reaching a minimum concentration of about 1.3 pCi/g at 16 ft, and then steadily increase from 16.5 to about 21 ft. K-40 concentrations are relatively constant below about 23 ft.

Additional information and interpretations of log data are included in the main body of the Tank Summary Data Report for tank C-110.

Log Plot Notes:

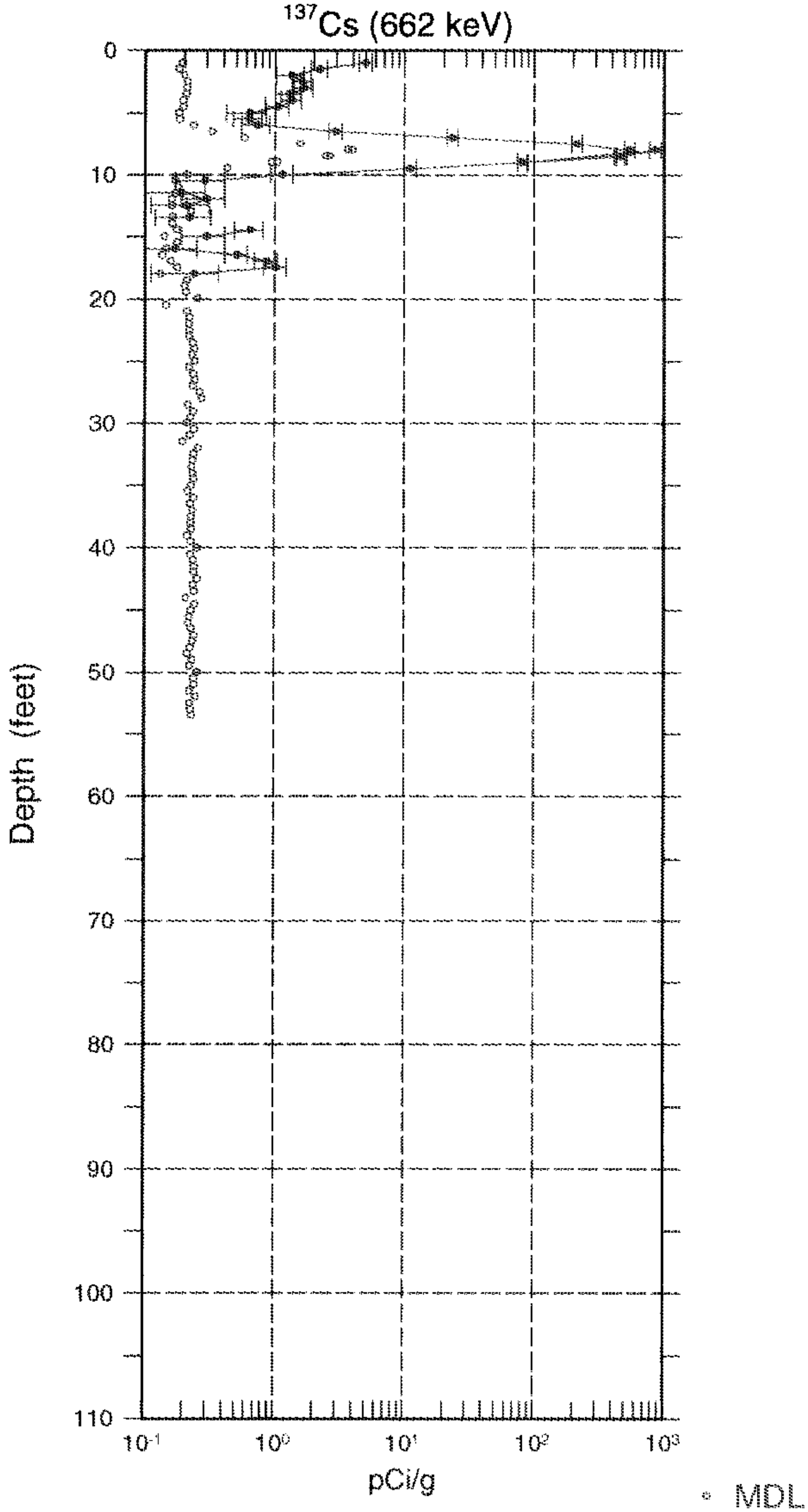
Separate log plots show the man-made and the naturally occurring radionuclides. The natural radionuclides can be used for lithology interpretations. The headings of the plots identify the specific gamma rays used to calculate the concentrations.

Uncertainty bars on the plots show the statistical uncertainties for the measurements as 95-percent confidence intervals. Open circles on the plots give the MDL. The MDL of a radionuclide represents the lowest concentration at which positive identification of a gamma-ray peak is statistically defensible.

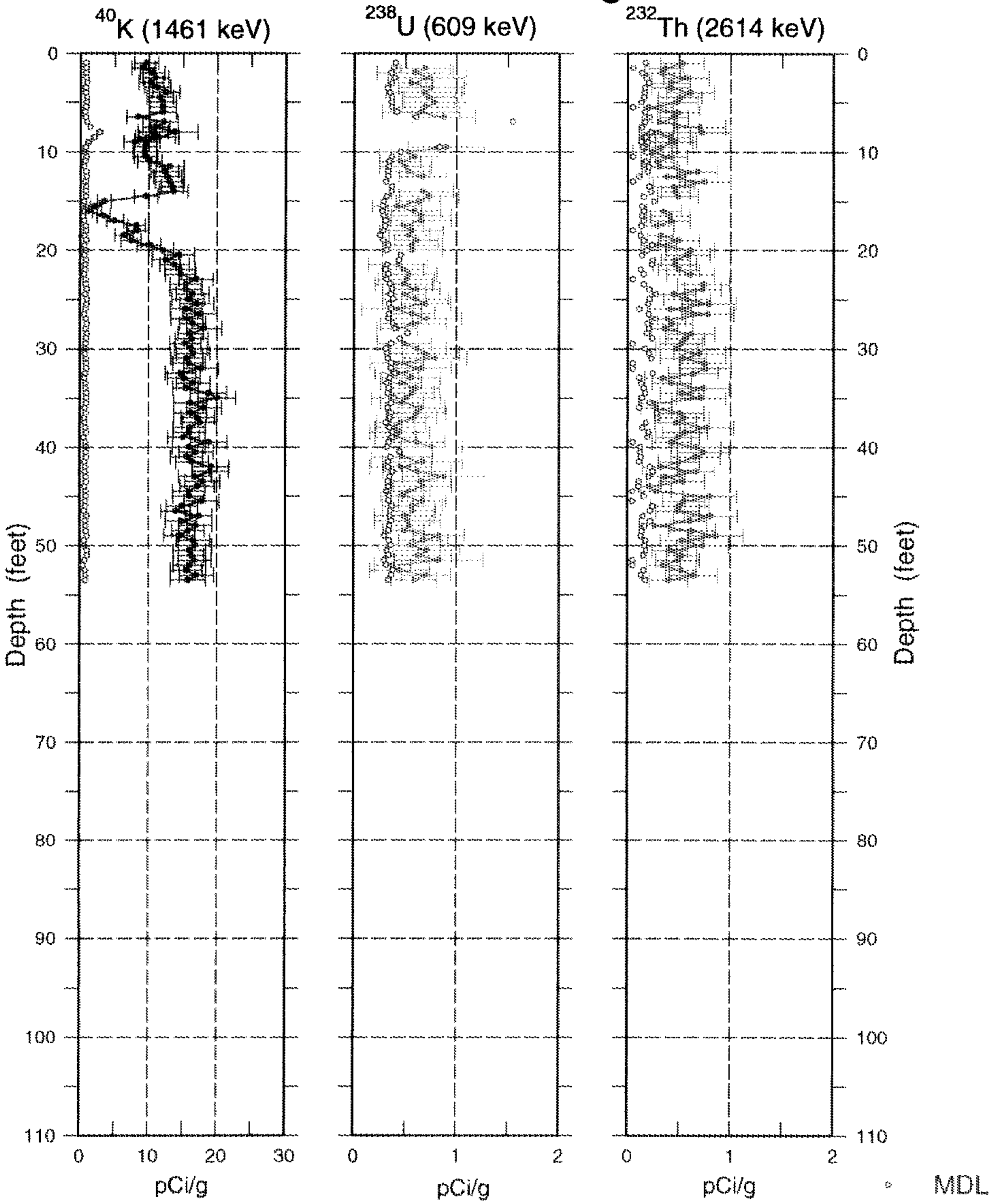
A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with the SGLS data.

30-00-22

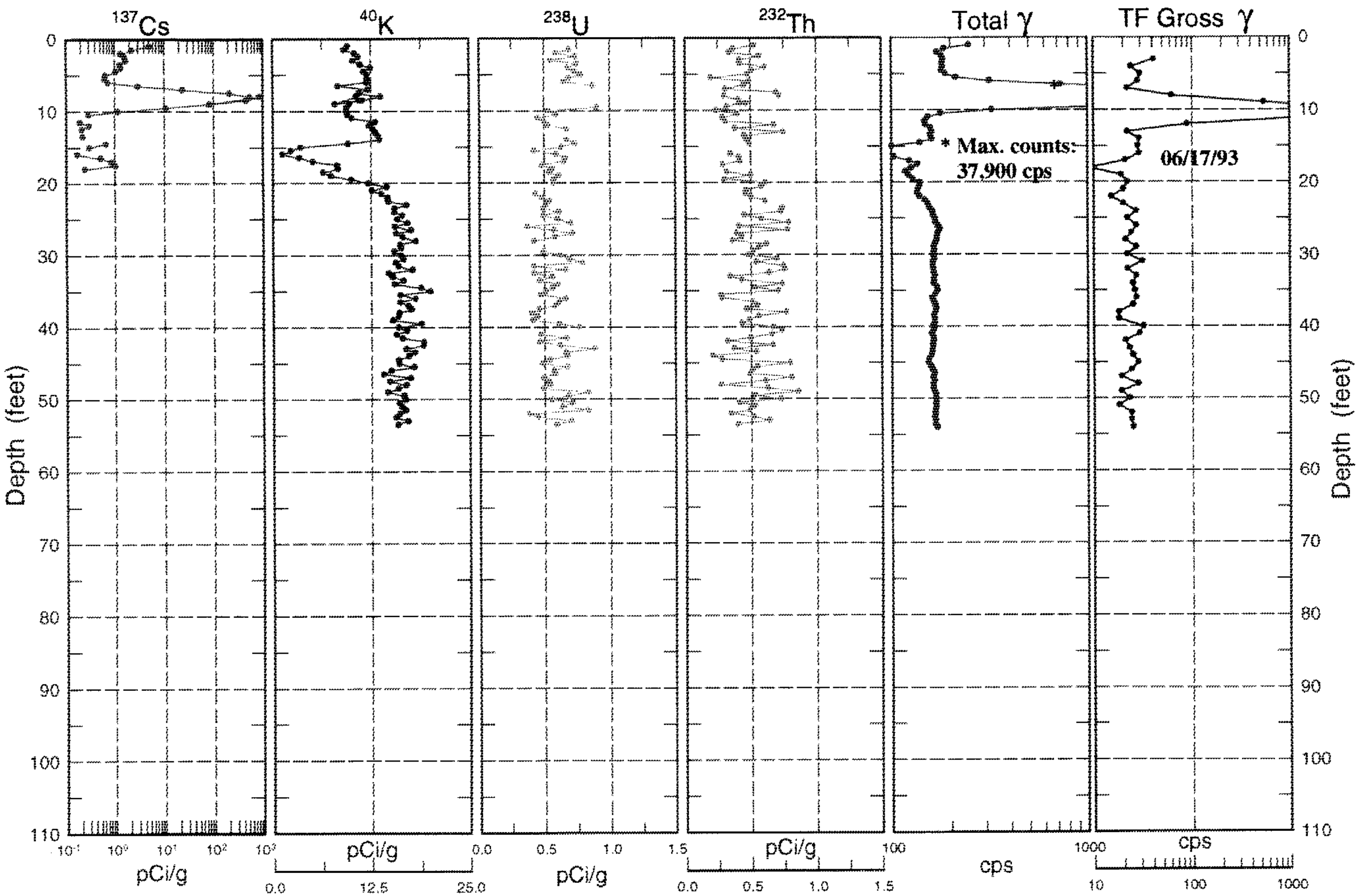
Man-Made Radionuclide Concentrations



30-00-22
Natural Gamma Logs



30-00-22 Combination Plot



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Spectral Gamma-Ray Borehole
Log Data Report

Log Event A

Borehole 30-00-24

Borehole Information

Farm :	C	Tank :	C	Site Number :	299-E27-122
N-Coord :	42,840	W-Coord :	48,650	TOC Elevation :	Unknown
Water Level, ft :	56.40	Date Drilled :	3/31/77		

Casing Record

Type :	Steel-welded	Thickness :	0.280	ID, in. :	6
Top Depth, ft. :	0	Bottom Depth, ft. :	60		

Cement Bottom, ft. : 60 Cement Top, ft. : 0

Borehole Notes:
Borehole 30-00-24 was drilled in March 1977 to a depth of 60 ft with 6-in. casing. The casing thickness is presumed to be 0.280 in., on the basis of the published thickness for schedule-40, 6-in. steel tubing. No driller's log is available for this borehole so construction details from Chamness and Merz (1993) were used in preparing this report. Chamness and Merz (1993) note that the borehole casing was grouted, but give no details as to which interval(s) were grouted or how much grout was used. No mention is made of perforations and it is therefore assumed that the borehole casing was not perforated.

The top of the casing, which is the zero reference for the SGLS, is even with the ground surface. The total logging depth achieved by the SGLS was 58.5 ft.

Equipment Information

Logging System :	2	Detector Type :	HPGe	Detector Efficiency :	35.0 %
Calibration Date :	10/96	Calibration Reference :	GJO-HAN-13	Logging Procedure :	P-GJPO-1783

Log Run Information

Log Run Number :	1	Log Run Date :	4/3/97	Logging Engineer:	Bob Spatz
Start Depth, ft.:	58.5	Counting Time, sec.:	100	L/R : L	Shield : N
Finish Depth, ft. :	0.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a

Borehole 30-00-24

Log Event A

Analysis Information

Analyst : D.L. Parker

Data Processing Reference : MAC-VZCP 1.7.9 Analysis Date : 10/27/97

Analysis Notes :

This borehole was logged by the SGLS in one log run. The pre- and post-survey field verification spectra met the acceptance criteria established for the peak shape and detector efficiency, confirming that the SGLS was operating within specifications. The energy calibration and peak-shape calibration from these spectra were used to establish the peak resolution and channel-to-energy parameters used in processing the spectra acquired during the logging operation. No fine gain adjustments were necessary during the logging of this borehole.

Casing correction factors for a 0.280-in.-thick steel casing were applied during analysis.

The man-made radionuclide Cs-137 was detected around this borehole. The presence of Cs-137 was measured almost continuously from the ground surface to 8 ft and continuously from 20 to 22 ft. Single detections of low Cs-137 concentrations occur at depths of 15, 19, 24, 56.5, and 58.5 ft. A well-defined peak occurs at about 20 to 22 ft with a maximum Cs-137 concentration of about 0.8 pCi/g at 21 ft.

K-40 concentrations increase steadily from 1 to about 3.5 ft reaching a concentration of about 14.1 pCi/g, and then decrease sharply to about 8.4 pCi/g at about 6.5 ft. K-40 concentrations increase to about 5.4 pCi/g at 8 ft, and then gradually increase to about 10 pCi/g at 15 ft and remain at about this concentration to 18.5 ft. K-40 concentrations then increase to a background of about 15 pCi/g at 21 ft Additional information and interpretations of log data are included in the main body of the Tank Summary Data Report for tank C-110.

Log Plot Notes:

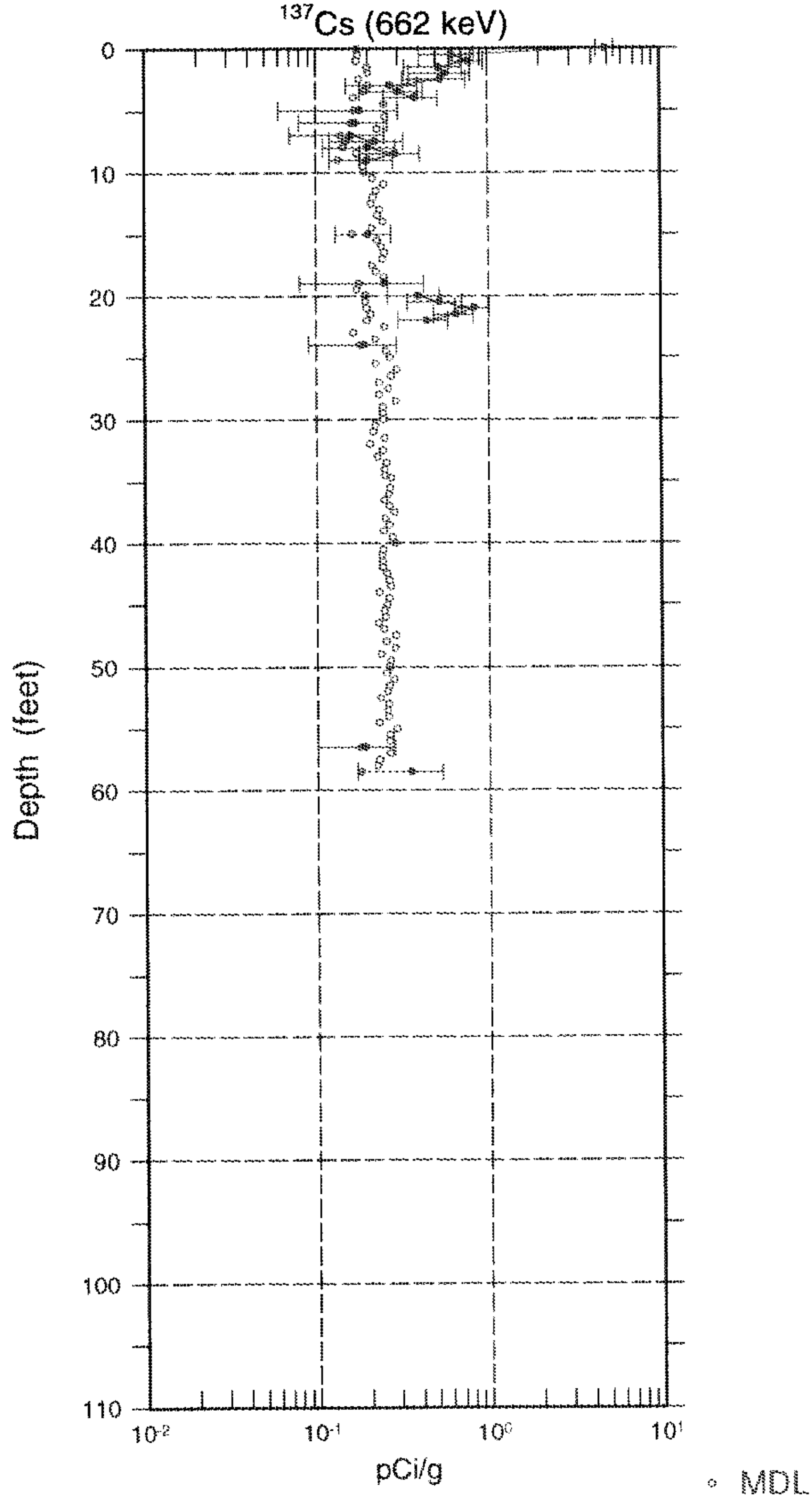
Separate log plots show the man-made and the naturally occurring radionuclides. The natural radionuclides can be used for lithology interpretations. The headings of the plots identify the specific gamma rays used to calculate the concentrations. Uncertainty bars on the plots show the statistical uncertainties for the measurements as 95-percent confidence intervals. Open circles on the plots give the MDL. The MDL of a radionuclide represents the lowest concentration at which positive identification of a gamma-ray peak is statistically defensible.

A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with the SGLS data.

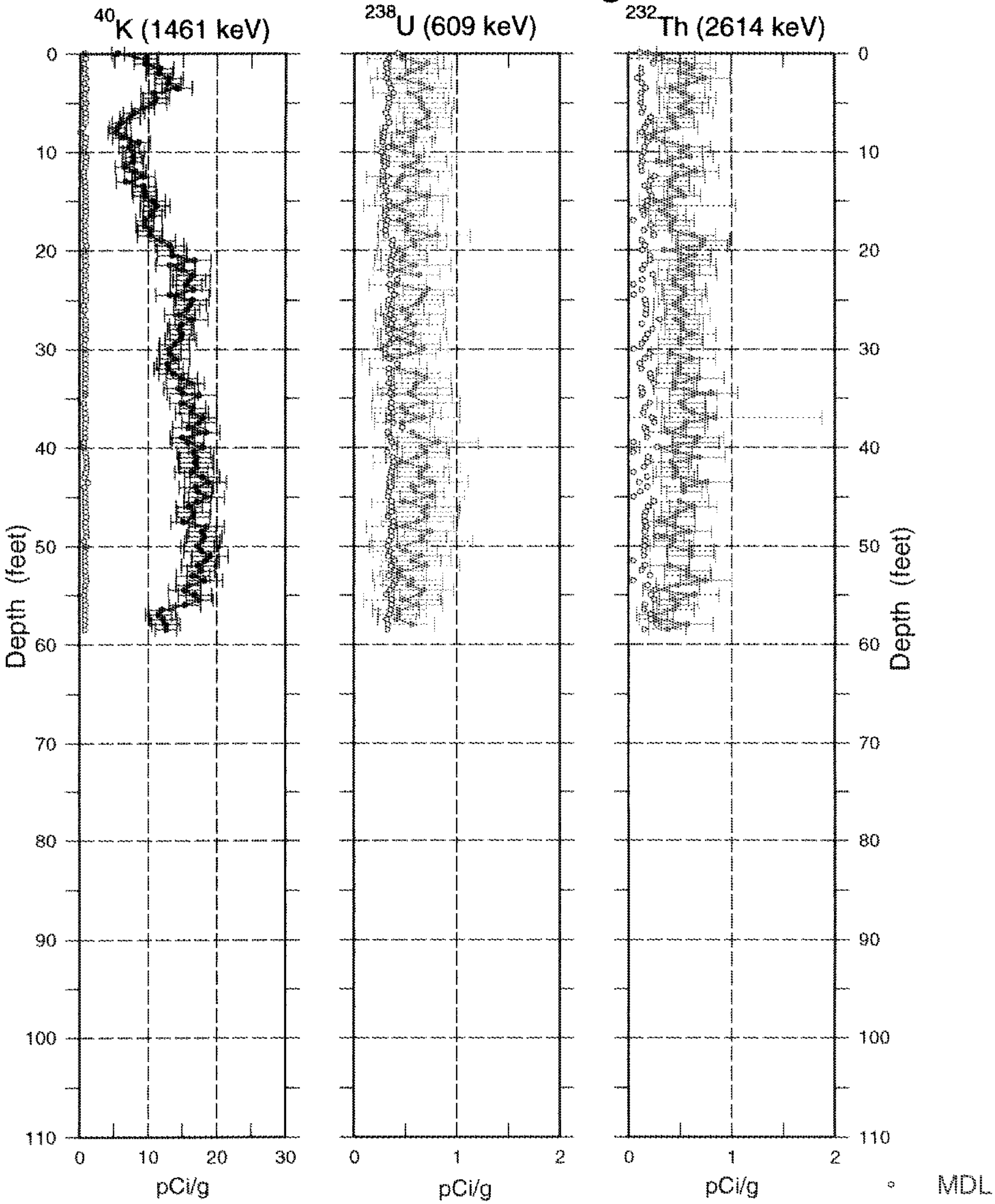
A plot of representative historical gross gamma-ray logs from 1977 to 1980 is included.

30-00-24

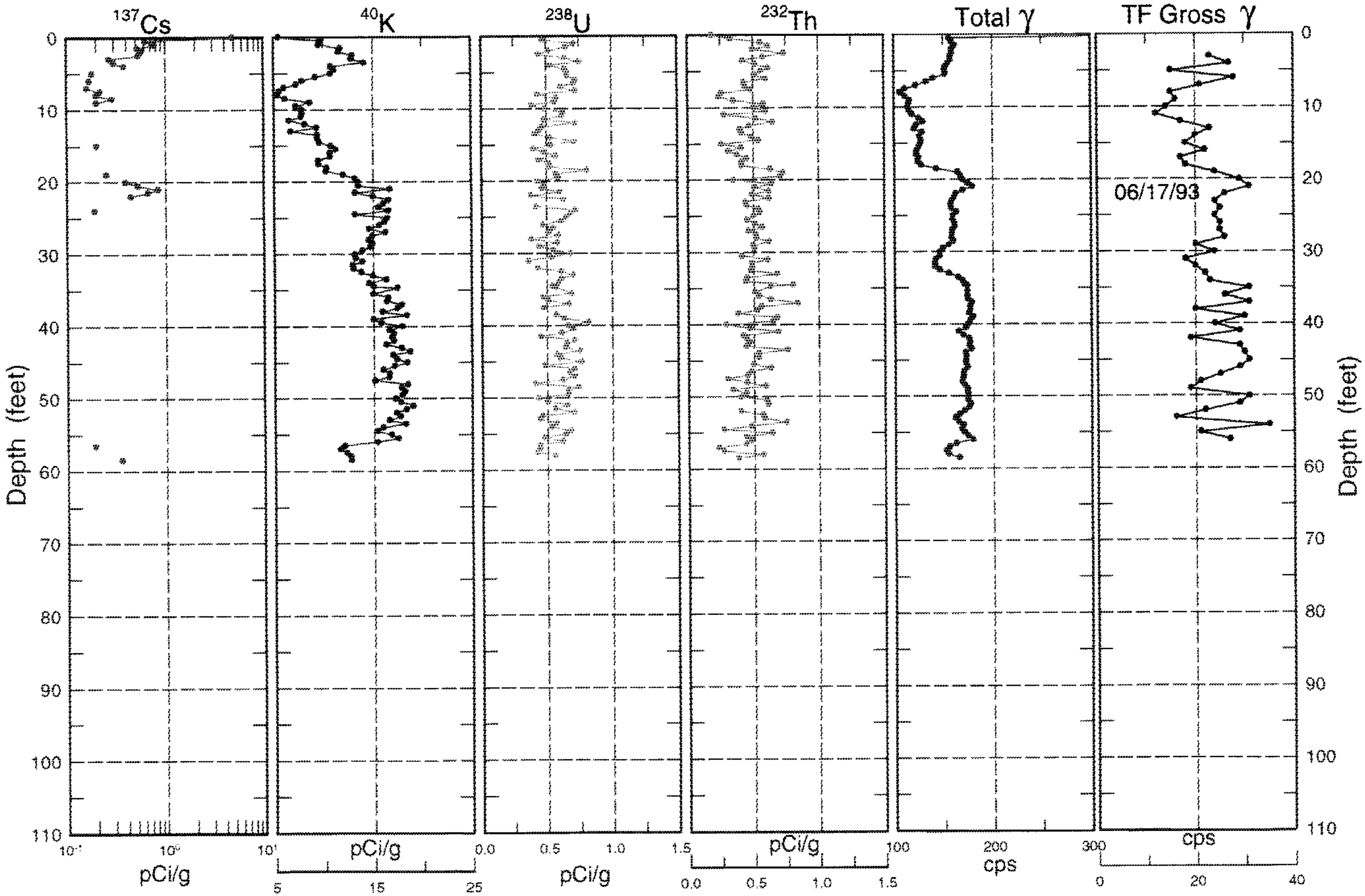
Man-Made Radionuclide Concentrations



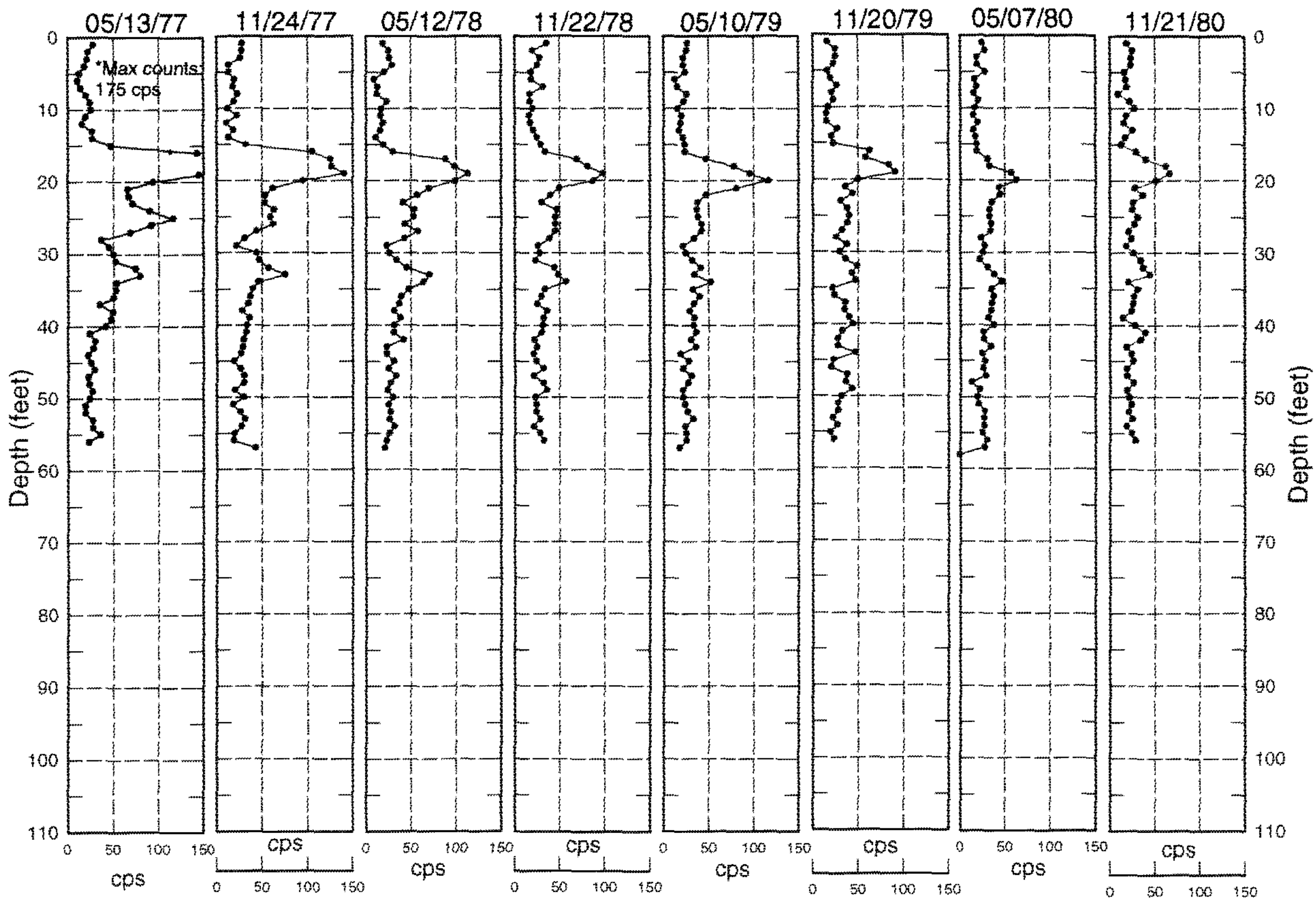
30-00-24
Natural Gamma Logs



30-00-24 Combination Plot



Historical Gross Gamma Logs for Borehole 30-00-24



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Spectral Gamma-Ray Borehole Log Data Report

Log Event A

Borehole 30-00-11

Borehole Information

Farm :	C	Tank :	C	Site Number :	299-E27-121
N-Coord :	42,840	W-Coord :	48,780	TOC Elevation :	Unknown
Water Level, ft :	None	Date Drilled :	3/31/77		

Casing Record

Type :	Steel-welded	Thickness :	0.280	ID, in. :	6
Top Depth, ft. :	0	Bottom Depth, ft. :	60		

Cement Bottom, ft. : 60 **Cement Top, ft. :** 0

Borehole Notes:
Borehole 30-00-11 was drilled in March 1977 to a depth of 60 ft with 6-in. casing. The casing thickness is presumed to be 0.280 in., on the basis of the published thickness for schedule-40, 6-in. steel tubing. No driller's log is available for this borehole so construction details from Chamness and Merz (1993) were used in preparing this report. Chamness and Merz (1993) note that the borehole casing was grouted, but give no details as to which interval(s) were grouted or how much grout was used. No mention is made of perforations and it is therefore assumed that the borehole casing was not perforated.

The top of this borehole is against an approximately 10-ft by 30-ft cover block. The top of the casing, which is the zero reference for the SGLS, is even with the ground surface. The total logging depth achieved by the SGLS was 58.5 ft.

Equipment Information

Logging System :	2	Detector Type :	HPGe	Detector Efficiency :	35.0 %
Calibration Date :	10/96	Calibration Reference :	GJO-HAN-13	Logging Procedure :	P-GJPO-1783

Log Run Information

Log Run Number :	1	Log Run Date :	4/17/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	0.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	13.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Log Run Number :	2	Log Run Date :	4/18/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	58.5	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	12.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Log Event A

Borehole 30-00-11

Analysis Information

Analyst : D.L. Parker

Data Processing Reference : MAC-VZCP 1.7.9 Analysis Date : 10/21/97

Analysis Notes :

This borehole was logged by the SGLS in two log runs. The pre- and post-survey field verification spectra met the acceptance criteria established for the peak shape and detector efficiency, confirming that the SGLS was operating within specifications. The energy calibration and peak-shape calibration from these spectra were used to establish the peak resolution and channel-to-energy parameters used in processing the spectra acquired during the logging operation. No fine gain adjustments were necessary during logging of this borehole.

Casing correction factors for a 0.280-in.-thick steel casing were applied during analysis.

The man-made radionuclide Cs-137 was detected around this borehole. The presence of Cs-137 was measured almost continuously from the ground surface to a depth of 17.5 ft. The Cs-137 concentrations from ground surface to about 11 ft are higher than the concentrations below 11 ft. A region of high Cs-137 concentrations occurs from about 8.5 to 11 ft and includes a maximum Cs-137 concentration of 2.9 pCi/g at 10.5 ft.

K-40 concentrations are somewhat variable from 1 to 22 ft. K-40 concentrations increase steadily from 1 to about 3.5 ft reaching a concentration of about 15.8 pCi/g, and then decrease to about 11 to 12 pCi/g from about 6 to 11 ft. K-40 concentrations increase steadily to a background of about 17 pCi/g. It was not possible to identify many of the 609-keV peaks used to derive the U-238 concentrations between about 9.5 and 11 ft.

Additional information and interpretations of log data are included in the main body of the Tank Summary Data Report for tank C-110.

Log Plot Notes:

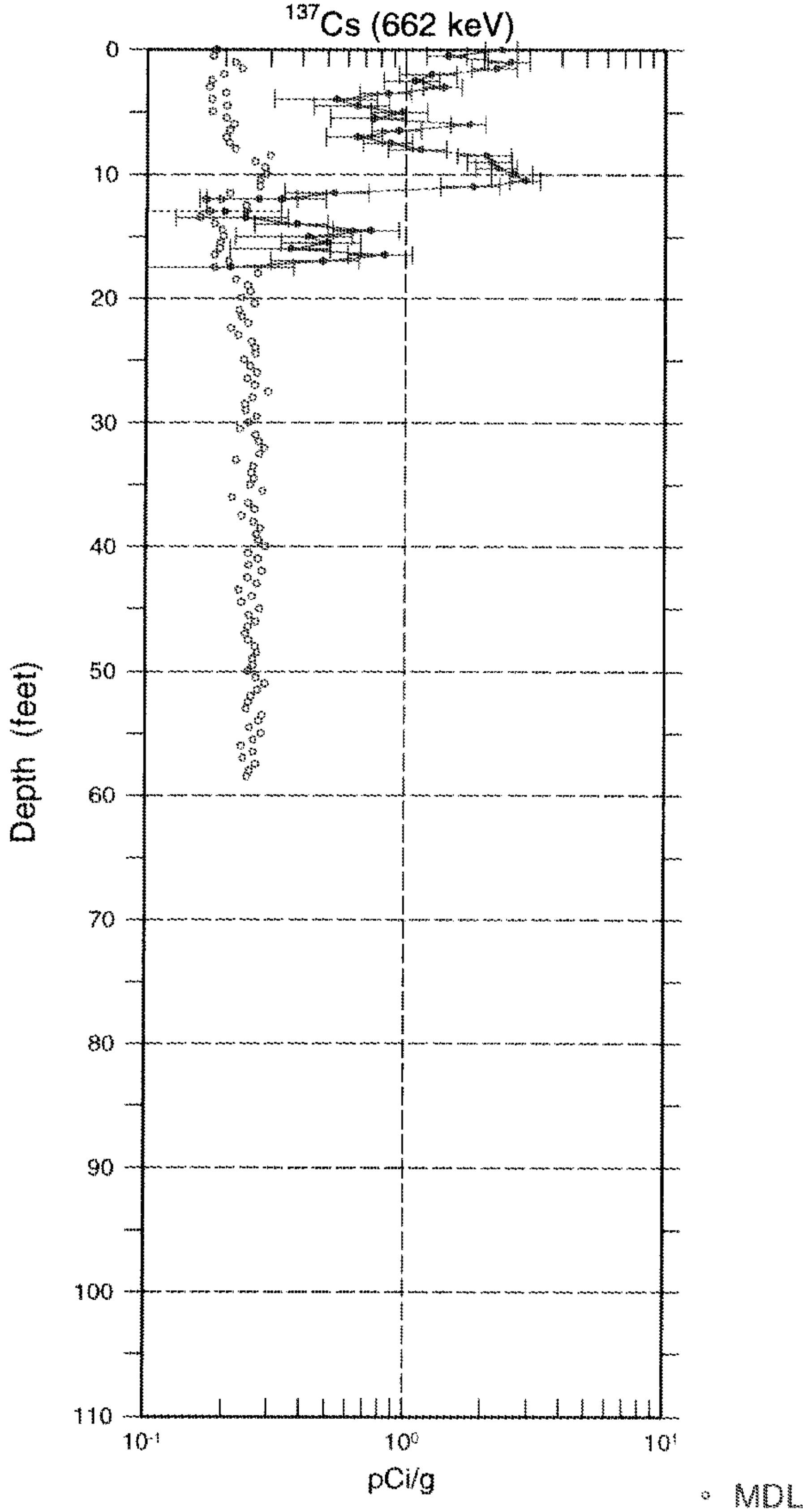
Separate log plots show the man-made and the naturally occurring radionuclides. The natural radionuclides can be used for lithology interpretations. The headings of the plots identify the specific gamma rays used to calculate the concentrations. Uncertainty bars on the plots show the statistical uncertainties for the measurements as 95-percent confidence intervals. Open circles on the plots give the MDL. The MDL of a radionuclide represents the lowest concentration at which positive identification of a gamma-ray peak is statistically defensible.

A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with the SGLS data.

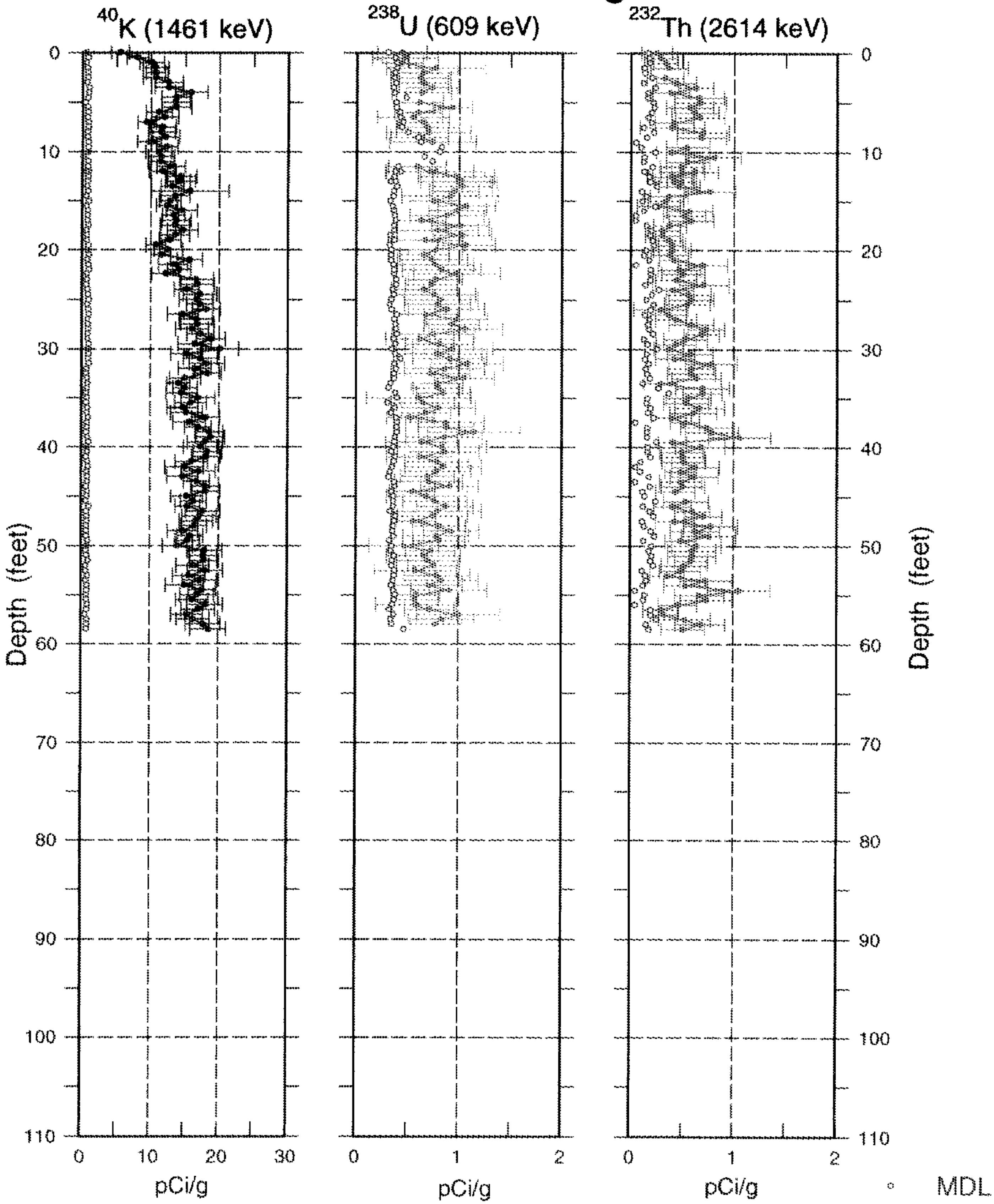
A plot of representative historical gross gamma-ray logs from 1977 to 1980 is included.

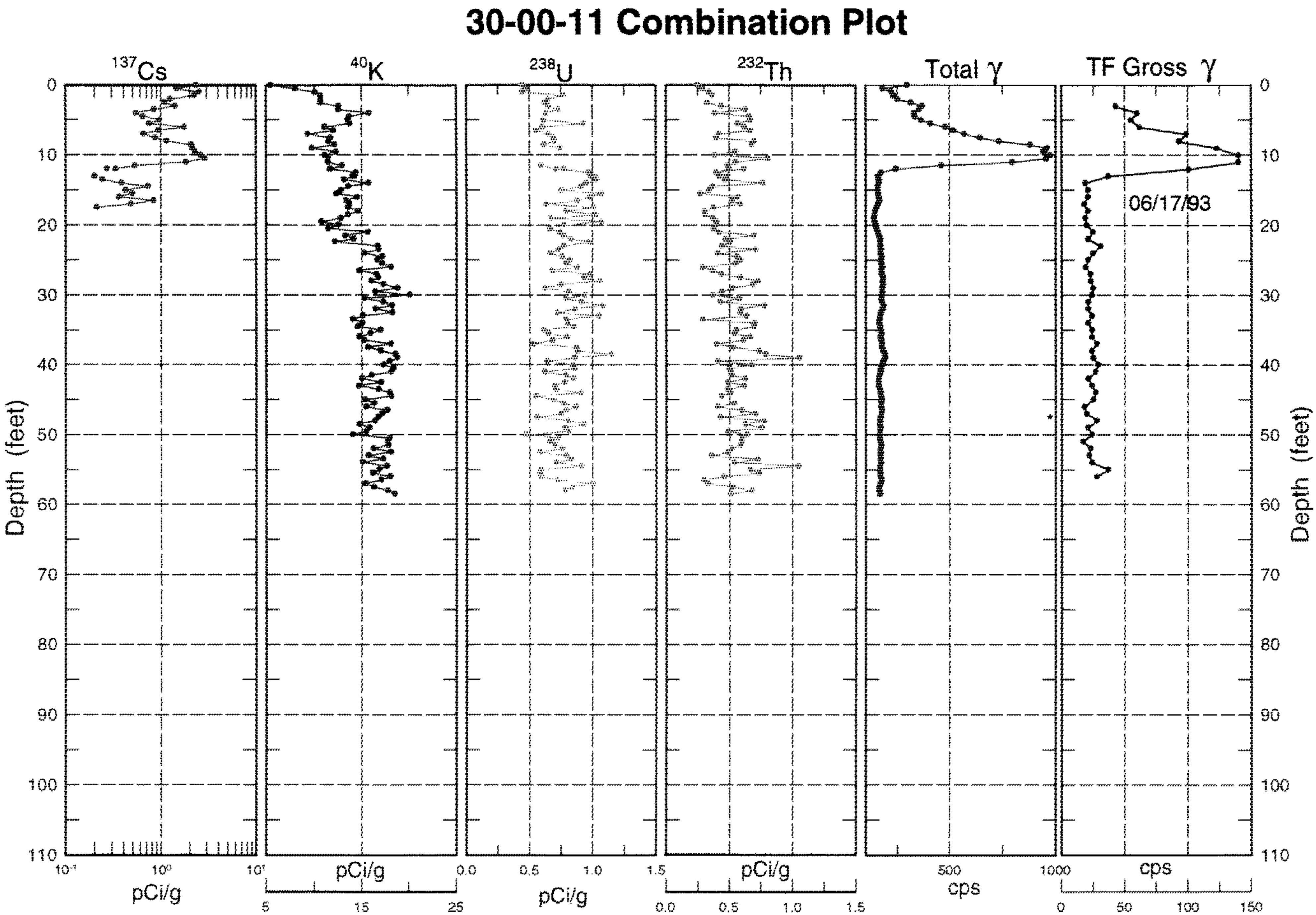
30-00-11

Man-Made Radionuclide Concentrations



30-00-11
Natural Gamma Logs





30-00-11 Combination Plot
137Cs
40K
238U
232Th
Total γ
TF Gross γ
Depth (feet)
06/17/93
pCi/g
cps

Historical Gross Gamma Logs for Borehole 30-00-11